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FEASIBILITY STUDY
ARTIFICIAL RECHARGE IN THE PRAIRIE PROVINCES

Volume I

Unpublished Report

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MANAGEMENT PERSPECTIVE

Present and projected water demands, particularly in the Prairies are reaching and, in a few areas, have already surpassed existing supplies, raising the prospect of serious water shortages in the not too distant future. The problem is compounded by the uncertainities associated with the possibility of climatic change, which may have very important but at present unknown implications for water supplies across the country.

One possible solution to the problem is to decrease water demands through measures such as water pricing; IWL is actively engaged in promoting this strategy.

Another approach is to increase available supplies. One of the more obvious ways of increasing overall supplies is to intercept and store spring flood flows for use throughout the remainder of the year. In the past this has been accomplished by the creation of surface water impoundments through the construction of dams and dikes. This approach has a number of disadvantages including cost, destruction of valuable arable land and wildlife habitat, losses caused by evaporation and, in some cases, severe ecological impacts.

An alternative to surface water storage is to store the "surplus" spring flood flows underground through artificial recharge - a procedure which could avoid many of the problems associated with surface water storage. To date few investigations have addressed ths possibility, so that the technical and economic feasibility of using artificial recharge to augment existing surface and ground water supplies is unknown.

This feasibility study is a first step towards assessing the possibility of storing water from spring flood flows in Prairie aquifers through artificial recharge. The stored water would be available for later use during periods of low flows.

For seven major rivers in the Prairie Provinces, the percentage of spring flood flow (the amount of water in the stream in excess of that required to maintain the low summer flow) averages thrity percent. Large scale aquifers are located near each of these rivers and near the major cities in the region. The quality of the stream water is realtively good compared with that of the adjacent ground water although some problems may result from higher temperatures, and higher phenol and sulphate concentrations in the stream water. This preliminary assessment indicates that artificial recharge in the Prairie Provinces might well be feasible. More detailed research should be undertaken at one or two locations in order to further assess the technical feasibility of implementing artifical recharge on a variety of scales before proceeding with assessments of economic feasibility.

PERSPECTIVE DE GESTION

La demande actuelle et la demande projetée d'eau, particulièrement dans les Prairies atteignent et, dans certains secteurs, ont déjà dépassé les réserves existantes, ce qui offre la perspective de graves pénuries d'eau dans un avenir pas trop éloigné. Le problème est encore compliqué par les incertitudes liées à la possibilité d'un changement climatique, qui pourrait avoir des répercussions très importantes mais que l'on ignore encore sur les réserves d'eau du pays.

Une solution possible au problème est de réduire la demande d'eau par des mesures tel que l'établissement du prix de l'eau; la DGET s'occupe de promouvoir activement cette stratégie.

Une autre méthode est d'accroître les réserves disponibles. L'une des façons les plus évidentes d'accroître les réserves globales est d'intercepter et de stocker les débits de crue du printemps pour s'en servir pendant le restant de l'année. Dans le passé, cet objectif a été accompli en créant des bassins d'accumulation des eaux de surface, en construisant des barrages et des digues. Cette méthode a un certain nombre de désavantages, notamment le coût, la destruction de terres arables et d'habitats fauniques de grande valeur, les pertes causées par l'évaporation et, dans certains cas, les répercussions écologiques graves.

Une solution autre que le stockage des eaux de surface est d'entreposer l'écoulement de crue du printemps sous terre par une alimentation artificielle - méthode qui pourrait éviter bon nombre des problèmes liés au stockage des eaux de surface. Jusqu'à présent, cette possibilité a été peu étudiée, de sorte qu'on ignore la faisabilité technique et économique d'utiliser l'alimentation artificielle pour accroître les réserves existantes d'eau de surface et d'eau souterraine.

Cette étude de faisabilité est une première étape en vue d'évaluer la possibilité de stocker l'eau d'écoulement de crue de printemps dans les nappes aquifères des Prairies par l'alimentation artificielle. L'eau stockée pourrait être utilisée plus tard pendant les périodes de débit minimum.

Pour les sept principales rivières des provinces des Prairies, le pourcentage d'écoulement de cru de printemps (c'est-à-dire la quantité d'eau dans le cours d'eau qui dépasse ce qui est requis pour maintenir le débit minimum d'été) s'élève en moyenne à trente pour cent. Des nappes aquifères importantes sont situées près de chacune de ces rivières et près des grandes villes de la région. La qualité de l'eau des cours d'eau est relativement bonne comparée à celle des eaux souterraines voisines, bien que certains problèmes puissent résulter des températures plus élevées et d'une teneur plus élevée en phénol et en sulphate dans l'eau du cours d'eau. Cette évaluation préliminaire indique que l'alimentation artificielle pourrait bien être possible dans les provinces des Prairies. Il faudrait entreprendre des recherches plus détaillées à un ou deux endroits afin d'évaluer davantage la faisabilité technique de procéder à l'alimentation artificielle à diverses échelles avant d'entreprendre les évaluations de faisabilité économique.

ABSTRACT

This study assesses the feasibility of using stream water to artificially recharge aquifers in the Prairie Provinces. The feasibility is assessed by examining the percentage of stream flow that occurs as flood flow, the location of major aquifers, the quality of stream water, and the quality of aquifer water. The percentage of flow occurring as flood flow varies considerably from year to year. At most of the sites examined, flood flow was a significant proportion of the total stream flow, averaging 30%. There is a wide distribution of large scale aquifers in the Prairies, with large aquifers located close to most of the major cities. The quality of stream water is relatively good. Stream water during the high flow season (April to July), the water that would be available for artificial recharge, tends to have lower total dissolved solids than the adjacent groundwater, and similar iron and manganese concentrations. However, for artificial recharge there may be problems associated with higher temperatures, high phenol and sulphate concentrations, and possibly also with high concentrations of organic substances or trace elements in the stream water. Preliminary assessment suggests that artificial recharge in the Prairie Provinces is feasible and further research should be undertaken.

RESUME

Cette étude évalue la faisabilité d'utiliser l'eau des cours d'eau pour alimenter artificiellement les nappes aquifères des provinces des Prairies. La faisaibilité de ce projet est évaluée en examinant le pourcentage d'écoulement qui se produit en débit de crue, l'emplacement des principales nappes aquifères, la qualité de l'eau des cours d'eau et la qualité de l'eau des nappes aquifères. Le pourcentage de l'écoulement se produisant en débit de crue varie considérablement d'une année à l'autre. Dans la plupart des endroits examinés, le débit de crue représentait une proportion importante du débit total du cours d'eau, s'élevant en moyenne à trente pour cent. Il y a une vaste répartition de nappes aquifères importantes dans les Prairies, et bon nombre d'entre elles se trouvent à proximité de la plupart des grandes villes. La qualité de l'eau des cours d'eau est relativement bonne. Pendant la saison de débit élevé (d'avril à juillet), l'eau des cours d'eau qui pourrait être utilisée pour l'alimentation artificielle tend à avoir une teneur totale en matières solubles en solution inférieure à l'eau souterraine voisine, et des teneurs semblables en fer et en manganèse. Cependant, dans le cas de l'alimentation artificielle, il pourrait y avoir des problèmes liés aux températures élevées, à une teneur élevée en phénol et en sulphate, et peut-être aussi à une teneur élevée de substances organiques ou oligo-éléments dans le cours d'eau. Les premières évaluations indiquent que l'alimentation artificielle est réalisable dans les provinces des Prairies et qu'il faudrait entreprendre des recherches plus approfondies.

OBJECTIVE

The objective of this Artificial Recharge Feasibility Study was to examine the suitability of undertaking further research on aquifer recharge in the Prairie Provinces. This was accomplished by these procedures:

1. estimating the quantity of water that would be available for artificial recharge (i.e. recharge of an aquifer with stream water) in the Prairie Provinces of Alberta, Saskatchewan, and Manitoba

2. locating the positions of known large scale aquifers in these provinces

3. determining the quality of stream water at selected stations on major Prairie Rivers, and

4. determining the water quality of aquifers in close proximity to the surface water quality stations.

WATER QUANTITY ESTIMATIONS

Procedure

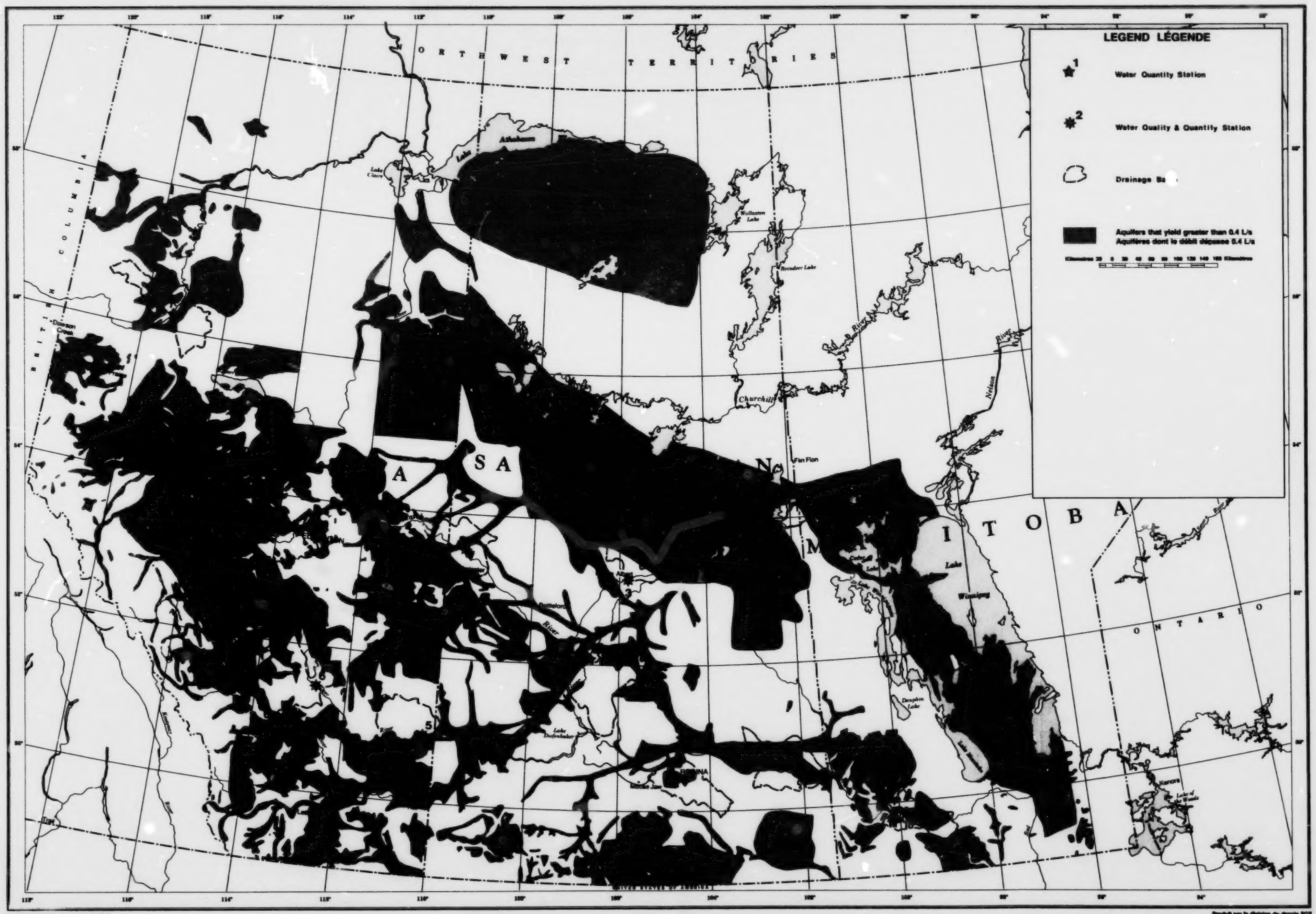
The stream discharge records of major rivers in the Prairie Provinces were examined to estimate the maximum quantity of water that would be available for artificial recharge. The study site locations were chosen to give good geographical coverage of the populated regions of Alberta, Saskatchewan, and Manitoba (figure 1). Continuous records from twelve gauging stations on seven major rivers in these provinces were examined. In addition, the flow records of two minor tributaries were compared to the flow records of major streams (table 1) (Environment Canada, 1985 a, b, c, d, and e).

For each gauging station, four years were chosen: a year of extremely high total discharge, a year of extremely low total discharge, and two years with intermediate discharge values. Whenever possible, flow records for the same four years were used for stations on the same river, but the years chosen are not usually the same for stations on different rivers. For two stations, records from eleven and twelve year periods were also examined in order to identify the annual variation in discharge.

FIGURE 1

SAMPLING STATION AND AQUIFER LOCATION MAP

PRAIRIE REGION — RÉGION DES PRAIRIES



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Ministère de l'environnement, 1984.

The percentage of flow occurring as flood flow was calcuated for every station for each of the years. For the purposes of this study flood flow is defined as that portion of the stream flow occurring during major spring runoff or summer peak flow conditions which is greater than the estimated base flow. Monthly hydrographs proved to have too little detail to permit separation of the base flow component, so hydrographs showing average daily discharge values were used. The base flow component was distinguished from the flood flow using a graphic method described by Wilson (1983). A line joining the points of greatest curvature on the rising and receding limbs of the flood peaks was used as the division between base flow and flood flow. The points of greatest curvature were approximated visually when possible and mathematically when necessary (figure 2). A planimeter was used to measure the relative areas beneath the base flow and flood flow curves, which were then used to calculate the percentage of flood flow. While this method underestimates the baseflow, and consequently overestimates flood flow component resulting flood flow value is useful for the purpose of the present study. The value is a measure of the volume of water available above the minimum volume of water present in the river during the low flow months of summer. Consequently, this value represents the volume of water available for recharge.

TABLE 1

SAMPLING STATIONS

#	NAME	NAT/REG	WATER QUALITY YEARS EXAMINED	WATER QUANTITY YEARS EXAMINED
1a	Assiniboine River at Brandon	regulated	1974-1978	55,61-70
1b	Assiniboine River near Brandon	regulated		75
2	Qu'Appelle River near Welby	regulated	1975-1982	76,77,79,82
3	North Saskatchewan River at Prince Albert	regulated	1974-1978	65,75,78,82
4	North Saskatchewan River at Deer Creek	regulated	1974-1982	74,75,78,82
5	Red Deer River at Bindloss	regulated	1974-1982	65,82,83,84
6	Red Deer River at Drumheller	regulated	1974-1982	65,82,83,84
7	North Saskatchewan River at Edmonton	regulated		65,73-82
8	Peace River at Peace River	regulated		68,76,78,84
9	Qu'Appelle River at Lumsden	regulated		76,77,79,82
10	Red River near Lockport	regulated		71,76,77,79
11	Red Deer River at Red Deer	regulated		65,82,83,84
12	South Saskatchewan River at Saskatoon	regulated		65,75,77,81
13	Little Saskatchewan River near Rivers	natural		76,77,79,82
14	Little Red Deer River near the mouth	regulated		65,82,83,84

The computer program BFINDEX (Swan and Condie, 1983) was used to calculate the Base Flow Index (equivalent to % base flow) for each of the gauging stations under study. These computed values, however, correlate very poorly with the values determined graphically (Appendix A). The two methods are based on different prinipcals, the BFINDEX program distinguishes base flow mathematically, using the minimum flow that occurs during five day periods to determine turning points of the base flow separation line. The technique is not equivalent to conventional methods of distinguishing the baseflow and flood flow components of stream water, and occassionally provides erroneous results (values greater than 1). The BFINDEX program, then, was judged to be of no use for the purposes of this study.

Discussion

At most of the gauging stations studied, river flow is not in its natural state but is regulated by upstream dams or other man-made structures. The flow discharge, the shape of the hydrographs, and possibly the percent of flood flow available are therefore modified from the natural state.

Flood flow typically occurs between April and August either as a single peak or as multiple peaks. At each station, the percentage of annual flow which occurs as flood flow varies considerably. Usually, flood flow percentages are lowest during years of extremely low total discharge, when they range from 0 to 30%, highest during years of extremely high total discharge, when they range from 30 to 81%, and intermediate during years of

less extreme total discharge. Based on the four years of records for each station, the mean flood flow ranges from 27% on the South Saskatchewan at Saskatoon to 58% on the Qu'Appelle near Lumsden. The average of these individual station means is 39% (Appendix A).

Althouth records from the two stations examined over eleven and twelve year periods give a better indication of year to year variation than the four year records, because the years of highest and lowest total discharge have been included in the four year records, the range of flood flow percentages over these longer periods differs little from the four year range. The mean flood flow percentage at a station when calculated from eleven or twelve years of data, however may differ significantly (+/- 12%) from that calculated for four years. None the less, the overall average flood flow probably would not differ significantly if more years of records were to be considered.

In addition to the flood flow calculations, all available hydrographs were qualitatively compared. The number of years that have a well defined flood peak, or peaks, varies considerably among the stations examined. The North Saskatchewan River has a well defined flood peak with a significant percentage of flood flow in virtually all years. Other rivers have well defined flood peaks except in years of extremely low total discharge (i.e. Assiniboine River, Red River, and the Peace River). In contrast, approximately one of every three years on the Qu'Appelle River is characterized by a very small or nonexistent flood peak. As well, most years on the South Saskatchewan River have small, poorly defined flood peaks. In fact, for nine of the seventeen years of hydrographs examined for the South Saskatchewan River, flow rates during the summer are the lowest of the year.

The records for gauging stations on the same river show a similar trend of flood peak definition through time. That is, in a given year all stations on the same river will have similar flood peaks. The volume of water associated with individual flood peaks, however, vary up to 25% between stations.

Values from gauging stations on two tributaries were compared to the closest station on a major river. The trend of the flood peaks of the Little Red Deer River correlate well with the closest station on the Red Deer River (at Red Deer), approximately 35 km away. Actual flood flow values are slightly higher (averaging +10%). However, the flood peaks and the percentage of flood flow on the Little Saskatchewan River do not correlate well with the Qu'Appelle River (near Welby), approximately 110 km away. This is probably a result of the greater distance between these gauging stations.

During most years, then, the majority of stations examined recorded flood peaks that are well defined and represent a significant proportion of the total stream flow. It appears, therefore, that sufficient quantities of water would be available for aquifer recharge at most locations in most years.

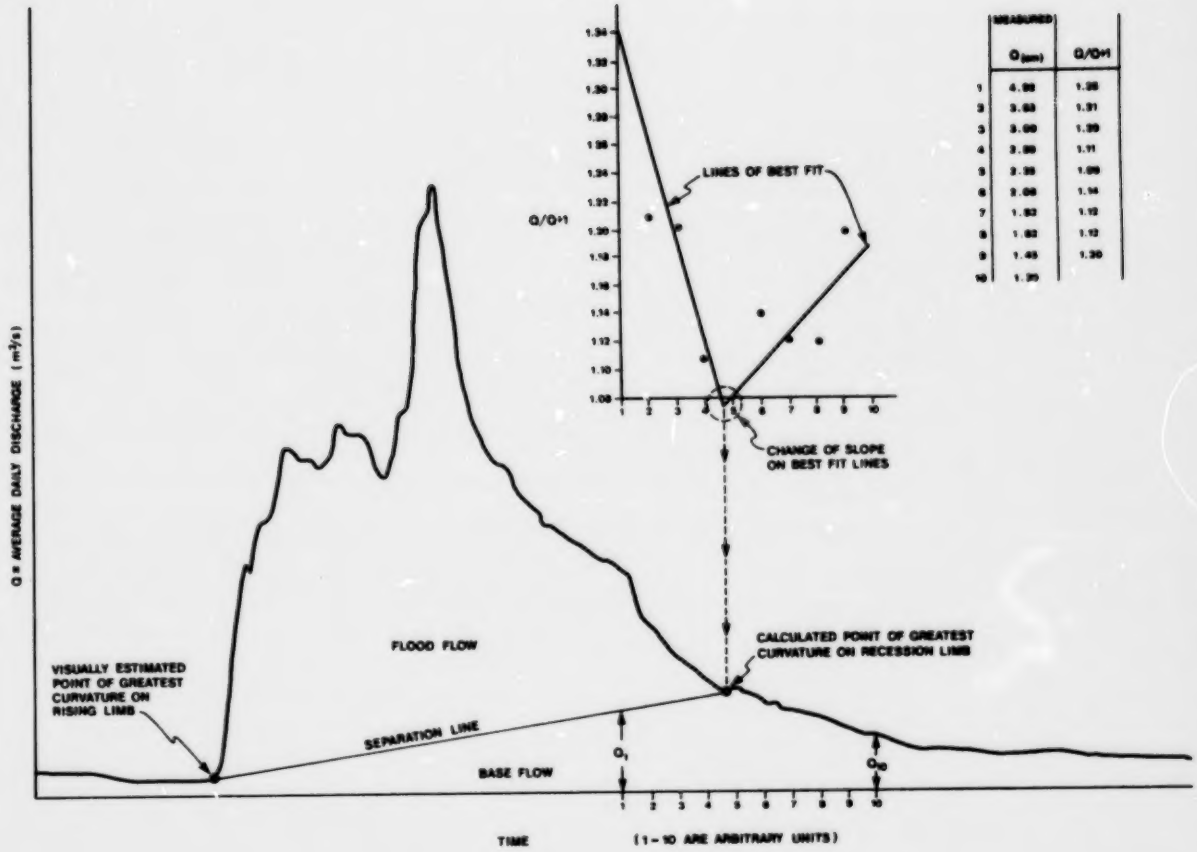

Figure 2: Example of Base Flow Separation on a Stream Hydrograph

AQUIFER LOCATION

The locations of large scale aquifers in the Prairie Provinces were taken from a map prepared by Hess (1986) (figure 1). Surficial and bedrock aquifers that yield more than 0.4 L/sec are shown on the map, but they are not differentiated. The sampling stations used in this study, along with their drainage basins are also illustrated (Fisheries and Environment Canada, 1978). More detailed information on the aquifers -- their type, locations and yields -- can be found in a MLM Ground-Water Engineering report (1979).

SURFACE WATER QUALITY

Procedure

Stream water at selected sites in the Prairie Provinces was examined to estimate the quality of water that would be available for artificial recharge (Environment Canada, 1984 a, b, c, and 1985 a). Six water quality stations, located at or very near the locations of six of the water quantity gauging stations, were examined for every year since 1974 for which data was available. Between four and nine years of data were available for each station (table 1).

Water temperature, total dissolved solids (TDS), and total alkalinity were used as water quality indicators. Data, for the high flow season (April to July), for the low flow season (September to February), and for the entire year were examined separately. Mean, minimum, and maximum values were calculated (tables 2, 3, 4). Detailed information can be found in Appendices D, E, F, G, H, and I.

In addition, the high flow season data (April to July) were examined in more detail in order to document turbidity, the concentrations of iron, manganese, and sulphate, and the occurrence of both trace elements and organics in quantities greater than half the maximum acceptable concentration defined by the Guidelines for Canadian Drinking Water Quality (Health and Welfare, 1978) (Appendix B). These substances include cadmium, grease and oil, phenolic material, and Nitrilotriacetic Acid (NTA) (table 5).

Discussion

Water temperature is fairly consistent among the stations examined, with both mean and maximum temperatures varying only 2 or 3 degrees Celsius. Minimum temperatures are more variable, (up to 6^{o}C). The temperature ranges from 6.9 to 27.6^{o}C and averages 19.8^{o}C. As might be expected, the temperatures are higher in the high flow months (April to July) than in the low flow months (September to February), averaging 20.9^{o}C during high flow and 18.7^{o}C during low flow.

TABLE 2

SURFACE WATER QUALITY - AVERAGE VALUES

STATION NAME	TEMPERATURE (C)			TOTAL DISSOLVED SOLIDS (mg/L			TOTAL ALKALINITY (mg/L)		
	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN
Assiniboine River at Brandon	20.2	24.7	12.9	614	969	254	245	352	113
Qu'appelle River near Welby	19.5	25.1	9.6	967	1466	281	283	418	97
N. Saskatchewan R. at Prince Albert	20.3	24.1	12.6	235	304	196	147	170	116
N. Saskatchewan R. near Deer Creek	19.6	26.7	11.7	200	272	131	131	218	81
Red Deer River at Bindloss	20	27.6	6.9	301	589	182	195	417	40
Red Deer River at Drumheller	19.1	24.1	6.9	242	440	155	177	345	103
AVERAGE	19.8	25.4	10.1	427	673	200	196	320	92
MAX	20.3	27.6	12.9	967	1466	281	283	418	116
MIN	19.1	24.1	6.9	200	272	131	131	170	40

TABLE 3

SURFACE WATER QUALITY - HIGH FLOW SEASON (APRIL-JULY)

STATION NAME	TEMPERATURE (C)			TOTAL DISSOLVED SOLIDS (mg/L			TOTAL ALKALINITY (mg/L)		
	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN
Assiniboine River at Brandon	21.0	24.7	18.9	455	624	254	186	291	113
Qu'appelle River near Welby	19.8	23.6	9.6	872	1466	281	254	357	97
N. Saskatchewan R. at Prince Albert	22.5	24.1	20.7	235	304	208	137	170	116
N. Saskatchewan R. near Deer Creek	21.2	26.7	13.1	188	230	131	123	155	81
Red Deer River at Bindloss	21.0	27.6	14.7	237	387	182	147	197	107
Red Deer River at Drumheller	20.0	24.1	12.5	201	335	159	144	189	118
AVERAGE	20.9	25.1	14.9	365	558	203	165	227	105
MAX	22.5	27.6	20.7	872	1466	281	254	357	118
MIN	19.8	23.6	9.6	188	230	131	123	155	81

TABLE 4

SURFACE WATER QUALITY - LOW FLOW SEASON (SEPT-FEB)

STATION NAME	TEMPERATURE (C)			TOTAL DISSOLVED SOLIDS (mg/L)			TOTAL ALKALINITY (mg/L)		
	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN
Assiniboine River at Brandon	19.2	22.7	12.9	686	969	509	270	352	194
Qu'appelle River near Welby	18.7	23.1	10.6	1043	1184	637	301	418	206
N. Saskatchewan R. at Prince Albert	18.3	21.1	12.6	238	263	196	154	164	129
N. Saskatchewan R. near Deer Creek	18.8	23.7	11.7	208	261	173	137	218	114
Red Deer River at Bindloss	19.2	23.6	6.9	350	589	201	232	417	40
Red Deer River at Drumheller	17.9	22.1	6.9	267	440	184	207	345	125
AVERAGE	18.7	22.7	10.3	465	618	317	217	319	135
MAX	19.2	23.7	12.9	1043	1184	637	301	418	206
MIN	17.9	21.1	6.9	208	261	173	137	164	40

TABLE 5

SURFACE WATER QUALITY DATA SUMMARY - HIGH FLOW SEASON (APRIL - JULY)

STATION		TEMP C	TDS mg/L	TOTAL ALKAL mg/L	TURB JTU	IRON extrb mg/L	IRON diss mg/L	MANG extrb mg/L	MANG diss mg/L	SO4 diss mg/L	CADMIUM extrb mg/L	CADMIUM tot-rec mg/L	PHENOLIC MATERIAL mg/L	OIL & GREASE mg/L	NTA NITRILOTR ACETIC AC mg/L
Qu'Appelle R. @ Welby	AVE	19.8	872	254	36	7.86	0.11	0.43	0.13	286	0.003	0.003	0.007	4.0	
	MAX	23.6	1466	357	145	78.00	0.18	1.79	0.60	440	0.001	0.001	0.001	1.0	
	MIN	9.6	281	97	4	0.34	0.04	0.06	0.02	9					
Assiniboine @ Brandon	AVE	20.9	455	186	74	2.30		0.30		164			0.013		
	MAX	24.7	624	291	125	4.30		0.50		224			0.027		
	MIN	18.9	254	113	10	0.20		0.20		83			0.001		
N. Sask R. @ Deer Creek	AVE	21.2	188	123	66	1.54	0.06	0.08	0.03	39	0.003		0.010	1.0	0.02
	MAX	26.7	230	155	52	18.00	0.09	0.61	0.03	54	0.002		0.001	1.0	0.02
	MIN	13.1	131	81	2	0.16	0.04	0.02	0.02	24					
N.Sask. R. @ P.A.	AVE	22.5	235	137	36	2.93		0.14		60	0.002		0.010		
	MAX	24.1	304	170	90	12.50		0.52		90	0.002		0.002		
	MIN	20.7	208	116	9	0.19		0.03		40					
Red Deer R. @ Drumheller	AVE	20.0	202	145	109	1.43	0.13	0.09	0.08	33	0.003		0.023		
	MAX	24.1	335	189	600	3.20	0.32	0.17	0.15	53	0.003		0.001		
	MIN	12.5	159	118	1	0.40	0.02	0.03	0.03	18					
Red Deer R. @ Bindloss	AVE	21.0	237	147	249	2.79		0.23		57					
	MAX	27.6	387	197	1054	7.20	0.1	0.9	0.03	128	0.002		0.033	2.0	
	MIN	14.7	182	107	14	0.36	0.05	0.06	0.03	24	0.001		0.001	1.0	
AVERAGE		20.9	365	165	95	3.14		0.21		106					
MAXIMUM		27.6	1466	357	1054	78.11	0.32	1.79	0.60	440	0.003	0.003	0.033	4.0	0.02
MINIMUM		9.6	131	81	1	0.19	0.02	0.02	0.02	9	0.001	0.001	0.001	1.0	0.02

The concentrations of total dissolved solids and total alkalinity vary considerably both at individual stations and from station to station. The average concentration of total dissolved solids is 427 mg/L, and it is calculated by averaging the individual station means, which range from 200 to 967 mg/L. Individual values range from a minimum of 131 mg/L to a maximum of 1466 mg/L. The average total alkalinity is 196 mg/L. Again, this is an average of station means, which range from 131 to 283 mg/L. Individual values range from a minimum of 40 mg/L to a maximum of 418 mg/L.

Because only high flow season water would be used for artificial recharge, the quality of this water is of primary importance for this study. The concentrations of total dissolved solids and total alkalinity are generally lower during the high flow months (April to July) than during the low flow months (September to February). During the high flow season, the concentrations of total dissolved solids average 365 mg/L, and range from 131 to 1466 mg/L. During the low flow months, TDS averages 465 mg/L. In the high flow season, the concentrations of total alkalinity average 165 mg/L, and range from 81 to 357 mg/L. In the low flow season total alkalinity averages 217 mg/L. High flow season temperatures average 20.9^{o}C, and range from 9.6 to 27.6^{o}C. Turbidity, during the high flow months, averages 95 JTU, and ranges from 1 to 1054 JTU.

Before 1980, total extractable iron and manganese concentrations are given in the surface water analyses. After this time, dissolved iron and manganese concentrations are given and the values are often less than the detection limit. Total extractable iron averages 3.14 mg/L and ranges from 0.19 to 78 mg/L; detectable dissolved iron ranges from 0.02 to 0.32 mg/L. Total extractable manganese averages 0.21 mg/L, and ranges from 0.02 to 1.79 mg/L; detectable dissolved manganese ranges from 0.02 to 0.6 mg/L.

Sulphate concentrations average 106 mg/L. Concentrations in the Qu'Appelle River at Welby are high averaging 286 mg/L with eighteen of the twenty-four values exceeding 250 mg/L. (The maximum acceptable concentration is 500 mg/L.) High concentrations were also recorded in the Assiniboine River at Brandon, where two of the four values were in the 200-225 mg/L range. All other stations show mean sulphate concentrations below the objective concentration, and the overall average sulphate concentration for these stations is less than 60 mg/L.

Cadmium appears in detectable concentrations of 0.001 to 0.003 mg/L on a number of occasions at five of the six stations. It is detected most often, on eight different occasions, at the Red Deer River station at Bindloss. (The maximum acceptable concentration is 0.005 mg/L) Phenolic material appears at all stations in concentrations above the detection limit, and above the maximum acceptable concentration of .002 mg/L. It is detected in quantities of 0.001 to 0.033 mg/L in about 90% of the analyses examined. Oil and grease were detected two or three times at three of the stations, in quantities of 1.0 to 4.0 mg/L. Nitrilotriacetic Acid (NTA) was detected in one sample at a concentration of 0.2 mg/L, but it was rarely tested for (The maximum acceptable concentration is 0.05 mg/L.) (McNeely, Neimanis and Dwyer, 1979).

AQUIFER WATER QUALITY AND AVAILABILITY

The quality and availability of water in aquifers located close to the six surface water quality stations was assessed. The type of information available ranged from detailed reports, to maps (from which data was extrapolated), to individual well water analyses. The following parameters were examined:

1. location, depth, thickness and lateral extent of aquifers

2. estimated yield of aquifers (from pumping rates of active wells, or from theoretical yields)

3. chemistry of the water (total dissolved solids, total alkalinity, and iron and manganese content), and

4. horizontal chemical changes within the aquifer.

As a result of the variation in the amount of information available, the above parameters could not be examined at all locations. Information on aquifers at each of the six sites is summarized individually (tables 6 to 9). Detailed information can be found in Appendix C.

TABLE 6

AQUIFERS NEAR THE ASSINIBOINE RIVER AT BRANDON

WELL	LOCATION	AQUIFER	ZONE SAMPLED metres from	to	PUMPING RATE L/sec	TDS mg/L	ALKAL mg/L	IRON mg/L
1	NW 4-7-13W1	sand	6.1	7.9	0.76	514	210	2.04
2	SW35-10-15W1	sand	13.4	14.3		391	330	1.64
3	SE13-11-15W1	sand	10.7	10.7		284	260	0.53
4	6-10-16W1	sand	27.4	36.6		336	272	0.11
5	SE 4-11-16W1	shale	86.3	87.2		1074	316	1.03
6	SE 4-11-16W1	sand	55.8	56.7		1658	150	0.24
7	SW35-10-18W1	s & g	3.7	4.3	2.05	341	175	
8	NW10-10-18W1	gravel	51.8	64.0	92.43	1633	264	0.72
9	NE18-10-18W1	g & s	74.7	93.6		1204	290	0.06
10	NE 8-10-18W1	gravel	2.7	3.7	2.27	502	323	
11	1-11-11-19W1	gravel	65.5	70.1	0.38	1871	184	1.00
12	1-11-11-19W1	gravel	108.8	113.4	0.19	1823	360	2.26
13	SE21-10-19W1	sand	39.6	39.6		1371	401	
AVERAGE			42.0	46.3	16.35	1000	272	0.96
MINIMUM			2.7	3.7	0.19	284	150	0.06
MAXIMUM			108.8	113.4	92.43	1871	401	2.26

(Sie and Little, 1976)

TABLE 7 - WATER QUALITY BASAL AQUIFER

Qu'Appelle River at Welby

Location	Depth	Fe	Cond.	Total Alka.
SE16-9-20-30-W1	182	8.30	2770	590
NW 7-17-20-30-W1	240	35.6	2900	521
NE 5-5-21-30-W1	240	5.80	2550	445
NW 5-19-21-30-W1	260	6.75	3100	341
NE13-27-20-31-W1	282	0.98	3550	403
NE 5-31-20-31-W1	185	4.5	3850	303
SW 5-33-20-31-W1	180	1.80	4200	325
SW 1- 1-20-32-W1	160	4.02	5100	321
NW15-28-20-32-W1	146	12.45	2600	447
NW 4-34-20-32-W1	140	1.53	2550	445
NW13-34-20- 1-W2	285	1.11	5550	630
AVERAGE		7.53	3520	434
MAXIMUM		35.6	2550	630
MINIMUM		0.98	5550	303

(Schreiner and Maathuis, 1982)

TABLE 8

GROUND WATER ADJACENT TO THE NORTH SASKATCHEWAN RIVER AT PRINCE ALBERT

WELL NO	ACQ. NO.	LOCATION	WELL DEPTH metres	DEPTH TO WATER metres	PUMPING RATE L/sec	CONDUCT micro-mho/cm	TDS (aprox) mg/L	TOTAL ALKAL mg/L	IRON mg/L	MANGANESE mg/L
1	1350	SW 5-12-48-26-W2				728	437	243		
2	1361	SW -33-49-27-W2	35.48	10.04	0.83	1560	936	304	2.78	1.00
3	1468	SE 8-29-49-25-W2	27.84	5.04	17.50	703	422	369	1.80	
4	1469	SE 8-29-49-25-W2	11.14	5.51	0.23	498	299	287	3.00	
5	1671	NW15-22-49-26-W2	16.46	9.75	0.91	141	85	59	7.30	0.19
6	1764	SE -9-48-26-W2	54.86	10.06	0.38	2660	1596	345	4.40	
7	1765	NE 1-30-47-26-W2	57.30	7.50	0.91	1070	642	307	1.00	
8	1766	SE 5-10-48-26-W2	94.49	7.62	0.76	3240	1944	304	0.80	
9	1767	SE 5-10-48-26-W2	94.49	7.62		3320	1992	313	1.50	
10	1769	NW15-22-49-26-W2	22.25	12.50	0.76	321	193	195	5.70	
11	1770	16-33-49-26-W2	49.26	24.08	0.19	1470	882	613	0.10	
12	1771	NW 4-10-50-26-W2	34.63	1.03	0.91	2230	1338	385	4.80	
13	1807	NE 14-3-49-27-W2	17.68	8.84	0.30	400	240	217	9.00	
14	2767	16-33-49-26-W2	49.26	24.08	0.19	1467	880	628	3.10	0.15
15	2773	NE 1-30-47-26-W2	57.30	7.50	0.91	844	506	302	8.30	0.60
16	2951	SE 11-3-50-26-W2	48.77	12.80	0.45	2016	1210	337	3.40	0.22
17	3437	NE 1-30-47-26-W2	57.30		0.91	827	496	325	11.00	0.56
18	3452	SE 3-4-50-26-W2	53.34	4.91	0.83	3000	1800	1580	2.40	0.07
19	3631	16-33-49-26-W2	49.10		0.19	1410	846	581	5.90	0.12
20	3642	NE 14-3-49-27-W2	17.68		0.30	532	319	227	3.10	0.30
21	3818	NE 14-3-49-27-W2	17.68		0.30	552	331	234	0.48	0.14
AVE			43.32	9.93	1.46	1380	828	388	3.99	0.34
MAX			94.49	24.08	17.50	3320	1992	1580	11.00	1.00
MIN			11.14	1.03	0.19	141	85	59	0.10	0.07

(Christiansen, 1973)

TABLE 9

GROUND WATER ADJACENT TO THE NORTH SASKATCHEWAN RIVER AT DEER CREEK

WELL NO	DATA SOURCE	ACO. NO/	LOCATION	WELL DEPTH metres	DEPTH TO WATER metres	DEPTH TO AQUIFER metres	PUMPING RATE L/sec	TDS mg/L	TOTAL ALKAL mg/L	IRON mg/L	MANG mg/L
1	SRC	2744	SE-36-50-25W3	48.29	12.19		0.23	1013	676	4.750	0.07
2	"	3444		80.24	21.88		0.68	702	564	1.900	0.08
3	RUTHERFORD		NE09-51-23W3	spring				1000	450		
4	"		SE 1-50-23W3	2.44				630	389	0.047	
5	"		NE32-50-23W3	3.65				385	235	0.029	
6	"		SE33-50-23W3	8.83				2140	494	0.018	
7	"		SE17-50-23W3	13.70				1070	479	0.007	
8	"		NE28-50-24W3	spring				620	370		
9	"		SW31-50-23W3	21.32				4760	275		
10	"		SW 6-50-23W3	22.84				2020	540		
11	"		NE10-50-24W3	50.24				1470	563	0.222	
12	"		SW36-53-24W3	12.18				900	467	0.107	
13	"		SW26-53-24W3	25.88				800	504	0.007	
14	"		SE21-51-24W3	5.18				1560	530		
15	"		NW31-53-25W3	4.57				470	279	0.011	
16	"		SW 7-54-25W3	5.48				700	485	0.129	
17	"		NE12-54-26W3	13.70				1730	724	0.000	
18	"		NW21-54-26W3	63.34				810	508	0.075	
19	"		SE34-53-26W3	10.96				5260	170		
20	"		NE33-53-27W3	15.83				2640	500		
21	"		NW20-52-26W3	9.74				1180	285		
22	"		SE 2-52-25W3	22.53				7240	285		
23	"		SW20-52-27W3	31.67				960	4652		
24	DOE	52720	SE06-52-26W3	34.71	20.42	22.3		900	374		0.04
25	"	39075	SE13-53-26W3	13.09	12.19			1700		1.000	
26	"	39076	15-53-26W3	4.87	4.27			10900		2.000	
27	"	39077	15-53-26W3	13.70	10.67			3150		3.000	
28	"	39080	NW04-54-26W3	3.35				575		0.500	
29	"	39083	21-54-26W3	54.81	30.48			720		3.000	
30	"	38961	SW34-52-24W3	110.53	40.23			2400		5.000	
31	"	38960	SW34-52-24W3	109.62	40.54			1700	707	5.000	0.15
32	"	38949	24-51-24W3	6.09	2.74			1200			
33	"	38947	SW17-51-24W3	9.74	6.10			2800	160	4.000	
34	"	38944	NE14-50-24W3	26.19	6.10	11.9		1300		6.100	
35	"	38976	SW05-50-25W3	12.79	10.97	11.0		3044			
36	"	52702	NW36-50-25W3	587.08	91.44	568.0		18300		0.700	
37	"	38988	08-51-25W3	18.27	6.10			2400			
38	"	38997	NE 5-52-25W3	4.26	3.35			1380	404	12.000	
39	"	39004	15-52-25W3	6.39	5.49			450	305	0.000	
40	"	39010	NW08-53-25W3	14.01	12.19			2200			
41	"	39011	NW09-53-25W3	3.05	1.83			900			
42	"	39013	SW21-53-25W3	2.44	0.61			780	358	0.000	
43	"	39014	08-54-25W3	10.66				1410	646	0.000	
44	"	39015	SE17-54-25W3	6.70	4.27			710		0.000	
AVERAGE				34.66	16.38			2250	579	1.772	0.09
MAXIMUM				587.08	91.44	568.0	0.68	18300	4652	12.000	0.15
MINIMUM				0.00	0.61	11.0	0.23	385	160	0.000	0.04

(Christiansen and Whitaker, 1973)

Aquifers adjacent to the Assiniboine River at Brandon

For the area adjacent to the Assiniboine River at Brandon, data from thirteen water analyses (Sie and Little, 1976) were assessed. The analyses were performed at wells in Townships 47 to 50, Ranges 25 to 28 West of the second meridian (figure 3).

The pumping rate in these wells averages 16 L/sec (range 0.2 to 92 L/sec). The concentrations of total dissolved solids averages 1000 mg/L (range 284 to 1870 mg/L). Alkalinity concentrations average 273 mg/L (range 150 to 401 mg/L). The concentration of iron in the well water averages 0.96 mg/L (range 0.06 to 2.26 mg/L) (table 6).

Aquifers adjacent to the Qu'Appelle River south of Welby

The area adjacent to the Qu'Appelle River at Welby contains part of the extensive Hatfield Valley (bedrock valley) Aquifer System (figure 4) (Schreiner and Maathuis, 1982). The Basal Aquifer of the Hatfield Valley Aquifer System lies within the area of interest (figure 5). It has an areal extent of approximately 950 km^2, an average thickness of 20 m (ranging from 5 to 90 m), and is overlain by 20 to 75 m (average of 50 m) of semiconfining glacial drift. There may also be some smaller intertill aquifers within the overlying glacial drift.

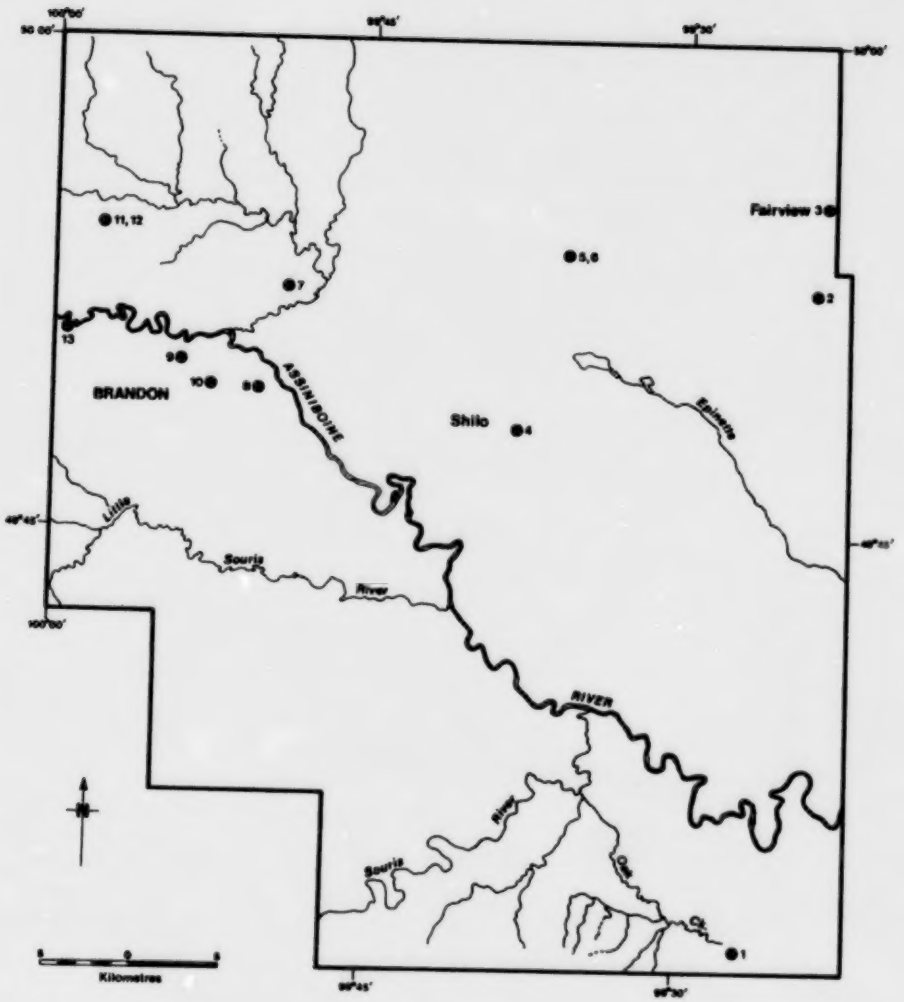

Figure 3: Well Location Map
Assiniboine River at Brandon

(Sie and Little, 1976)

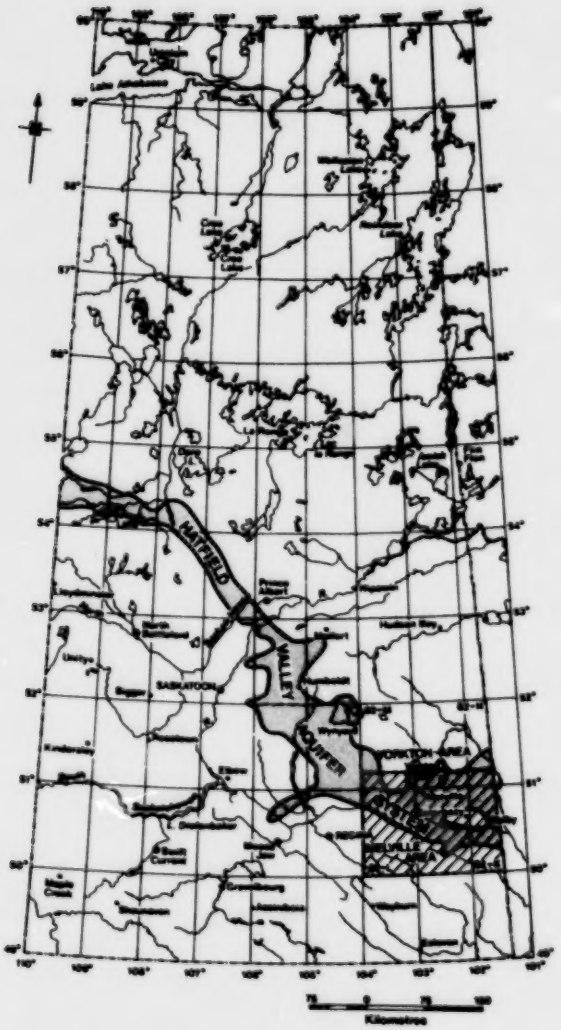

Figure 4: Location Map
Hatfield Valley Aquifer System

(Schreiner and Maathuis, 1982)

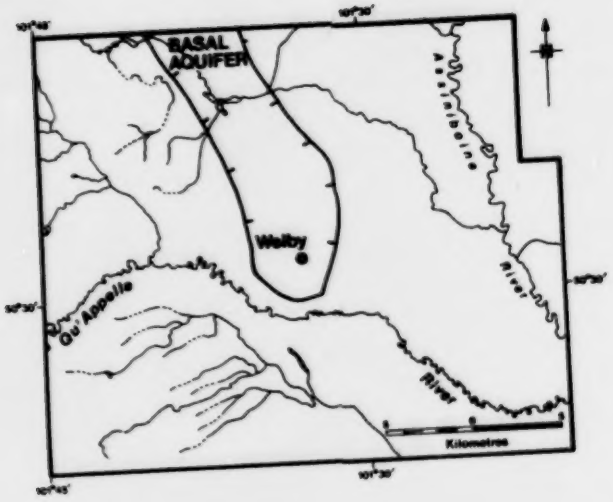

Figure 5: Aquifer Study Site
Qu'Appelle River at Welby

(Schreiner and Maathuis, 1982)

The hydraulic conductivity of the aquifer is estimated at 15 to 25 m/day. The estimated maximum yield of a well or well field is 25 L/sec. In addition, the net ground water yield of the Basal Aquifer is estimated to be 4.3×10^7 m^3/yr (1.3×10^3 L/sec).

The conductivity of water in the Basal Aquifer averages 3520 micromhos and ranges from 2550 to 5550 micromhos. This is the equivalent of an average total dissolved solids of 2110 mg/L and of a range from 1530 to 3330 mg/L (Hem, 1970). Total alkalinity averages 434 mg/L (range 303 to 630 mg/L). Iron content averages 6.53 mg/L (range 0.98 to 35.6 mg/L) (table 7).

Water quality and water type within the Basal Aquifer are variable. Generally, quality improves towards the Qu'Appelle River and the Assiniboine Valley as a result of accumulative addition by vertical recharge. Sodium-sulphate, calcium-magnesium-sulphate, sodium-chloride, and sodium-sulphate-chloride water types are present.

The water is generally unfit as a municipal drinking water supply. It is classified as very poor for domestic use, poor but usable for livestock, and not useable for irrigation.

Aquifers adjacent to the North Saskatchewan River at Prince Albert

Data from twenty-one Saskatchewan Research Council water analysis reports on wells in an area adjacent to the North Saskatchewan River at Prince Albert were assessed. The wells are located in Townships 47 to 50, Ranges 25 to 28 west of the second meridian was assessed (figure 6).

Well depth averages 43 meters (range 11 to 94 m). Depth to water averages 10 meters (range 1 to 24 m). The pumping rate in these wells averages 1.5 L/sec (range 0.2 to 17.5 L/sec). Conductivity averages 1380 micromhos/cm (range 141 to 3320 micromhos/cm), which corresponds to an average total dissolved solids of 830 mg/L (range 85 to 2000 mg/L) (Hem, 1970). Total alkalinity averages 388 mg/L (range 59 to 1580 mg/L). Iron concentrations in the well water average 4.0 mg/L (range 0.1 to 11.0 mg/L), and manganese concentrations average 0.34 mg/L (range 0.07 to 1.0 mg/L) (table 8).

Aquifers adjacent to the North Saskatchewan River at Deer Creek

For the area adjacent to the North Saskatchewan River at Deer Creek, data from fourty-four well water analyses were examined. Analyses by the Saskatchewan Research Council, the Saskatchewan Department of the Environment, and a report by Rutherford (1967) were used. The wells are in Townships 50 to 54, Ranges 23 to 27 west of the third meridian (figure 7).

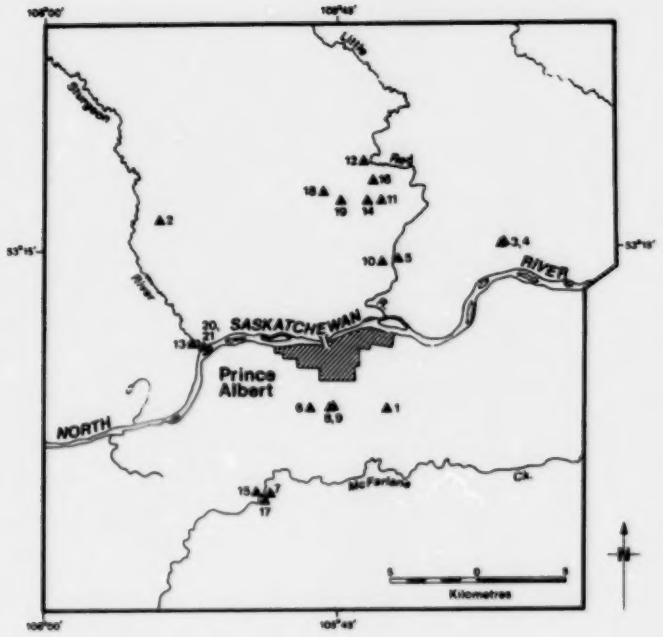

Figure 6: Well Location
North Saskatchewan River at Prince Albert

(Christiansen, 1973)

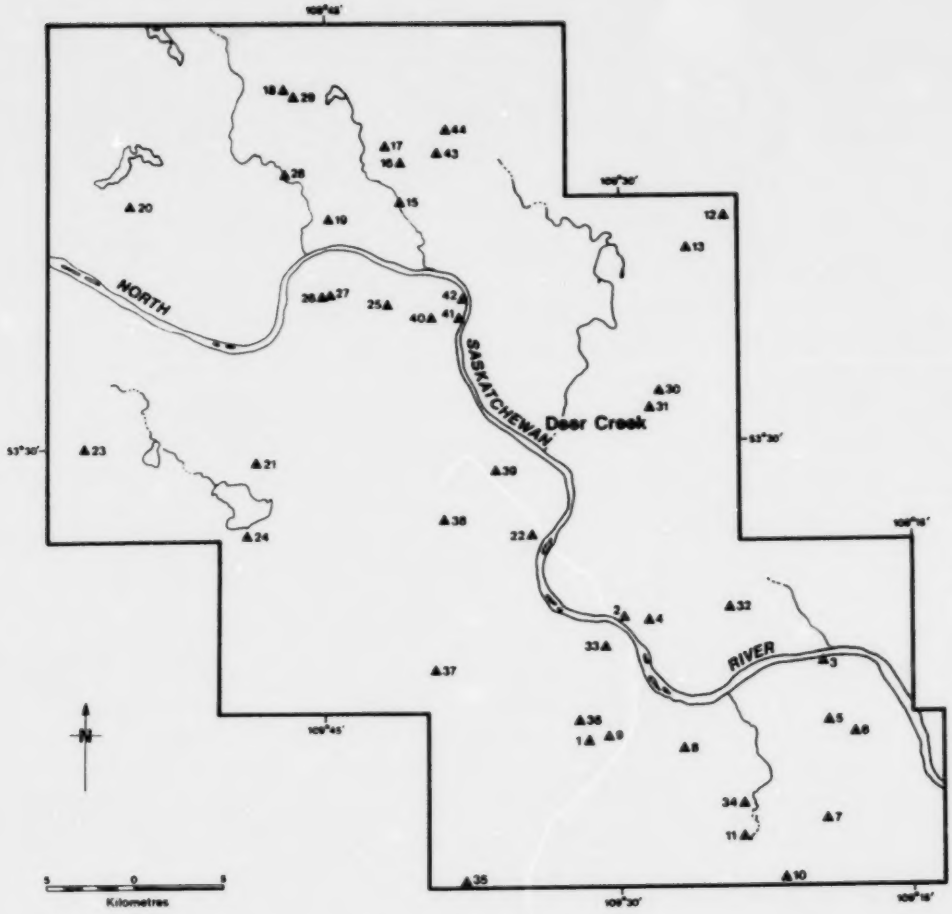

Figure 7: Well Location
North Saskatchewan River at Deer Creek

(Christiansen and Whitaker, 1973)

Well depth averages 35 meters, and ranges from 0 (springs) to 91 m. Depth to water averages 16 meters (range 0.6 to 91 m). Based on information from four of the wells, the depth to aquifer is between 11 and 568 m. The pumping rate which was measured at only two wells, is in the order of 0.23 L/sec to 0.68 L/sec.

The concentrations of total dissolved solids average 2250 mg/L (range 385 to 18300 mg/L). Total alkalinity averages 579 mg/L (range 160 to 4652 mg/L). Iron averages 1.8 mg/L (range 0 to 12 mg/L), and manganese averages 0.9 mg/L (range 0.04 to 0.15 mg/L) (table 9).

Aquifers adjacent to the Red Deer River near Bindloss

Aquifers in Townships 21 to 23, Ranges 1 to 5, West of the fourth meridian, an area adjacent to the Red Deer River near Bindloss, were examined (figure 8). The data was taken from a hydrogeological map published in an Alberta Research Council report by Stevenson and Borneuf (1975).

Well yields within the bedrock channel that covers most of the area are estimated at 2 to 8 L/sec. Small regions north of the river have yields of 0.07 to 0.4 L/sec, and areas in the northwest and southeast corners have yields of 0.4 to 2 L/sec. There are also a number of flowing wells in the area, with flows of 0.2 to 1 L/sec.

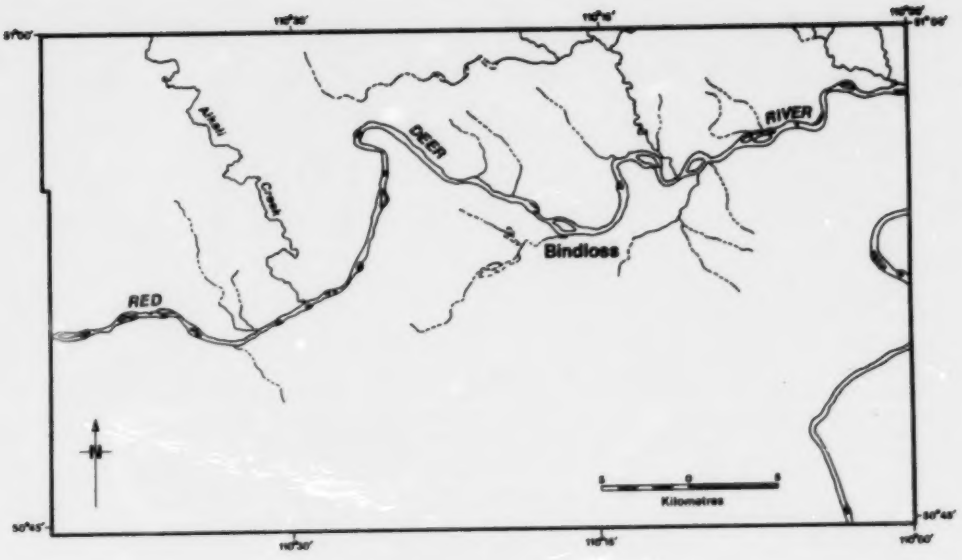

Figure 8: Aquifer Study Site
Red Deer River near Bindloss

(Stevensen and Borneuf, 1975)

The dominant water type in the Bindloss area is sodium bicarbonate. The concentrations of total dissolved solids in these waters ranges from less than 1000 to more than 3000 mg/L.

Surficial aquifers in upland areas, where local flow systems prevail, have calcium bicarbonate water with total dissolved solids generally less than 1000 mg/L. Surficial aquifers in lowland areas, where the ground water flow is regional have either sodium sulphate water with TDS greater than 3000 mg/L, or they have a mixture of water types and intermediate TDS values.

The buried valley has calcium sulphate, calcium bicarbonate, and sodium sulphate waters, or mixtures of these water types. The TDS is in the 1000 to 2000 mg/L range.

Water from bedrock aquifers in upland areas is of the sodium bicarbonate type and good for human consumption. The ground water in regional lows or from deep Foremost Formation aquifers, however, is of the sodium sulphate type and brackish, with TDS greater than 3000 mg/L.

Aquifers adjacent to the Red Deer River at Drumheller

Aquifers within an area 30 km by 20 km lying along the Red Deer River, at Drumheller were examined (figure 9).

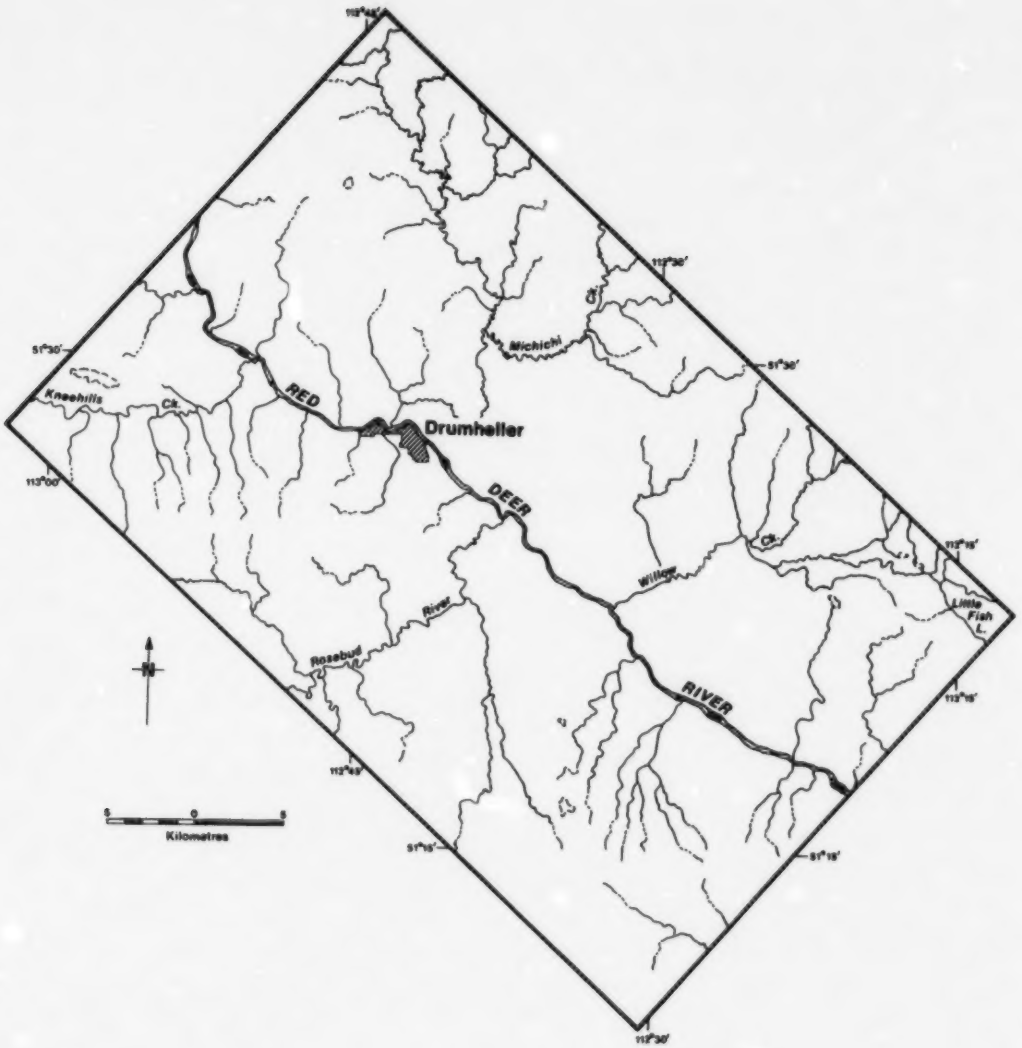

Figure 9: Aquifer Study Site
Red Deer River at Drumheller

(Borneuf, 1972)

According to estimated yields shown on the map of Borneuf's (1972) report, most of the area adjacent to the River has expected yields of 0.07 to 0.4 L/sec, with some regions having less than 0.07 L/sec, and some regions with up to 2.0 L/sec. The estimated 20-year safe yields from test wells in this area, however, show much higher yields (0.4, 2.1, 10.1 and 11.0 L/sec). The report gives no explanation for this discrepancy.

The concentrations of total dissolved solids in the Drumheller area aquifers average 1500 mg/L. The east side of the Red Deer River has high values which change rapidly over short distances, depending on groundwater flow patterns. Values of 1000-2000 mg/L are common, but some areas have up to 6000 mg/L. The west side of the river has more consistent values which are generally less than 2000 mg/L.

Most of the area is a discharge zone with mainly sodium bicarbonate groundwater. In the small recharge areas, the concentrations of total dissolved solids are less than 1500 mg/L, and the waters are of the carbonate - bicarbonate type. Occasional sulphate waters exist on the east side of the river, and these are more common on the west side.

Summary of Aquifer Water Quality

The available information on aquifer water chemistry is summarized in table 10. Combining the data from the sites produces the following averages: total dissolved solids 1600 mg/L, total alkalinity 420 mg/L, iron concentration 3.3 mg/L, and manganese concentration 0.21 mg/L. Alkalinity and iron values are only available for four of six sites and manganese content is available for two of six sites.

CONCLUSIONS

Based on four years of data from each of fourteen stations, the mean percentage of stream flow occurring as flood flow in the Prairie Provinces is 30%, and it ranges from 27% to 58% at any one station. The percentage of flood flow varies significantly from year to year. During most years the majority of stations examined have flood peaks that are well defined and represent a significant proportion of the total stream flow. Minor tributaries have approximately the same percentage of flood flow as the major rivers.

Stream water at the stations examined has an average temperature of 19.8^{o}C. The concentration of total dissolved solids and total alkalinity vary considerably both from station to station and at individual stations. The average concentration of TDS is 427 mg/L, and the average total alkalinity is 196 mg/L.

TABLE 10

SUMMARY OF AQUIFER WATER CHEMISTRY

SITE #	NAME	TDS mg/L	TOTAL ALK mg/L	IRON mg/L	MANG mg/L	WATER TYPE
1	Assiniboine River @ Brandon	1000 (284-1870)	273 (150-401)	0.96 (.06-2.26)		
2	Qu'Appelle River @ Welby	2110 (1530-3330)	434 (303-630)	6.53		sodium-sulphate calcium/magnesium-sulphate
3	North Saskatchewan R. @ Prince Albert	830 (85-2000)	388 (59-1580)	4.00 (0.10-11.00)	0.34 (0.07-1.00)	
4	North Saskatchewan R. @ Deer Creek	2250 (385-18300)	579 (160-4642)	1.80 (0.00-12.00)	0.09 (0.04-0.15)	
5	Red River @ Bindloss	(1000-)3000				mainly sodium bicarbonate
6	Red Deer River @ Drumheller	1500 ((1000-6000)				mainly sodium bicarbonate
AVERAGE		1600	420	3.30	0.21	

The quality of stream water during the high flow season is most significant for this study, since this is the water that would be available for artificial recharge. During the high flow season (April to July) water has higher temperatures, lower total dissolved solids, and lower total alkalinity than during the low flow season (September to February). The following are high flow season averages: temperature 20.9^{o}C, TDS 365 mg/L, turbidity 95 JTU, total alkalinity 165 mg/L, extractable iron 3.14 mg/L, and extractable manganese 0.21 mg/L. Sulphates occur in significant quantities (greater than half the maximum acceptable limit for human health) at two of the stations examined. Phenolic material occurs in quantities above the maximum acceptable limits for human health at all stations. Other trace elements and organics that may cause concern are cadmium, oil and grease, and Nitrilotriacetic acid (NTA). The quality of some of the stream water, then, may raise problems for artificial recharge, but overall the quality of the streamwater is good enough to consider using it to recharge aquifers.

The amount of information available on aquifer water quality varies considerably. The following averages, however, give some indication of the aquifer chemistry at the sites studied: TDS 1600 mg/L, total alkalinity 420 mg/L, iron 3.3 mg/L, and manganese 0.21 mg/L. The average concentrations of total dissolved solids, and of total alkalinity in the ground water are much higher than the average concentrations found in the stream water. Iron and manganese concentrations are about the same in both. There is no information on groundwater temperatures from any of the sites examined, but especially in the deep aquifers the temperature would be considerably lower (in the 4 to 10^{o}C range) than that of stream water.

In conclusion, artificial recharge in the Prairie Provinces appears to be feasible and further research should be undertaken. Large scale aquifers are widely distributed across the region, and large aquifers are located close to most of the major cities. Sufficient volumes of stream water occur as flood flow, and the water is of relatively good quality compared with the quality of groundwater in the region, and compared also with Health and Welfare standards. The stream water tends to have lower dissolved solids than the adjacent ground water, and similar iron and manganese concentrations. For aquifer recharge, however, there may be problems associated with the higher temperatures, with high phenol and sulphate concentrations, and possibly also with high concentrations of organic substances or trace elements in the stream water.

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APPENDIX A

SUMMARY OF WATER QUALITY CALCULATIONS

STATION NAME	STATION #	YEAR	% FLOOD FLOW	% BASE FLOW	OTTAWA'S BFI	TOTAL DISCHARGE CUBIC DECAMETERS	FLOOD DISCHARGE CUBIC DECAMETERS
Qu'Appelle River near Welby	05JM001	1976	56	44	.884	839,000	469,840
		1977	0	100	.777	90,600	0
Mean flood flow = 43		1979	67	33	.931	361,000	241,870
		1982	50	50	.857	250,000	125,000
Red Deer River near Bindloss	05CK004	1965	60	40	.644	3,740,000	2,244,000
		1982	49	51	.646	1,970,000	965,300
Mean flood flow = 43		1983	47	53	.720	1,240,000	582,800
		1984	15	85	.767	925,000	138,750
Red Deer River at Drumheller	05CE001	1965	62	38	.615	3,230,000	2,002,600
		1982	49	51	.610	1,690,000	828,100
Mean flood flow = 37		1983	29	71	.651	1,070,000	310,300
		1984	9	81	.762	758,000	68,220
Red Deer River at Red Deer	05CC002	1965	55	45	.623	2,660,000	1,463,000
		1982	52	48	.636	1,330,000	691,600
Mean flood flow = 38		1983	34	66	.713	969,000	329,460
		1984	11	89	.772	684,000	75,240
Red River near Lockport	050J010	1971	22	78	.669	5,830,000	1,282,600
		1976	41	59	.745	7,070,000	2,898,700
Mean flood flow = 30		1977	4	96	.809	1,610,000	64,400
		1979	55	45	1.257	12,200,000	6,710,000
South Saskatchewan River at Saskatoon	05HG001	1965	53	47	.693	10,900,000	5,777,000
		1975	24	76	.787	8,490,000	2,037,600
Mean flood flow = 27		1977	0	100	.824	3,910,000	0
		1981	33	67	.804	9,030,000	2,979,900
Assiniboine River at Brandon	05MH001	1955	63	37	.911	3,120,000	1,965,600
		1961	6	94	.870	127,000	7,620
Mean flood flow = 36		1970	39	61	.907	1,340,000	522,600
Near Brandon	05MH013	1975	38	62	.866	2,140,000	813,200

STATION NAME	STATION #	YEAR	% FLOOD FLOW	% BASE FLOW	OTTAWA'S BFI	TOTAL DISCHARGE CUBIC DECAMETERS	FLOOD DISCHARGE CUBIC DECAMETERS
North Saskatchewan River near Deer Creek	05EF001	1974	45	55	.742	9,170,000	4,126,500
		1975	18	82	.771	4,770,000	858,600
Mean flood flow = 35		1978	34	66	.782	7,750,000	2,635,000
		1982	42	58	.719	7,280,000	3,057,600
North Saskatchewan River at Edmonton, Alberta	05OF001	1965	62	38	.739	11,200,000	6,944,000
		1975	22	78	.790	4,430,000	974,600
Mean flood flow = 42		1978	36	64	.775	7,290,000	2,624,400
		1982	50	50	.584	6,860,000	3,430,000
North Saskatchewan River at Prince Albert, Sask.	05GG001	1965	63	47	.820	12,900,000	8,127,000
		1975	29	71	.822	5,370,000	1,557,300
Mean flood flow = 40		1978	31	69	.819	8,220,000	2,548,200
		1982	36	64	.746	7,920,000	2,851,200
Peace River at Peace River	07HA001	1968	33	67	.764	28,600,000	9,438,000
		1976	30	70	.801	74,500,000	22,350,000
Mean flood flow = 29		1978	12	88	.814	52,300,000	6,276,000
		1984	42	58	.816	63,000,000	26,460,000
Qu'Appelle River near Lumsden	05JF001	1976	81	9	.125	472,000	382,320
		1977	6	94	.716	53,900	3,234
Mean flood flow = 58		1979	72	28	.170	252,000	181,440
		1982	72	28	.184	351,000	252,720
Little Saskatchewan River near Rivers	05MF018	1976	33	67		280,000	
		1977	41	59		64,600	
(compare to Qu'Appelle at Welby)		1979	70	30		245,000	
Mean flood flow = 43		1982	29	71		89,800	
Little Red Deer River near the Mouth	05CB001	1965	67	33		346,000	
		1982	57	43		109,000	
(Compare to Red Deer at Red Deer, Alberta)		1983	44	56		77,800	
		1984	30	70		36,900	
Mean flood flow = 49							

STATION NAME	STATION #	YEAR	% FLOOD FLOW	% BASE FLOW	OTTAWA'S BFI	TOTAL DISCHARGE CUBIC DECAMETERS	FLOOD DISCHARGE CUBIC DECAMETERS
North Saskatchewan River at Edmonton	05OF001	1965	62	38	.756	11,200,000	6,944,000
		1973	35	65	.814	6,030,000	2,110,500
		1974	41	59	.681	7,280,000	2,984,800
		1975	22	78	.790	4,430,000	974,600
		1976	32	68	.702	5,280,000	1,689,600
		1977	34	66	.732	5,890,000	2,002,600
		1978	36	64	.775	7,290,000	2,624,400
		1979	20	80	.802	4,840,000	968,000
		1980	30	70	.715	7,570,000	2,271,000
		1981	38	62	.688	7,340,000	2,789,200
		1982	50	50	.584	6,860,000	3,430,000

% Flood Flow

Mean = 36
Range = 20 - 62

Assiniboine River @ Brandon	05MH001	1955	63	37	.911	3,120,000	1,965,600
		1961	6	94	.870	127,000	7,620
		1962	40	60	.425	304,000	121,600
		1963	42	58	.820	453,000	190,260
		1964	52	48	.731	434,000	225,680
		1965	63	37	.725	847,000	533,610
		1966	67	33	.854	868,000	581,560
		1967	65	35	1.074	748,000	486,200
		1968	28	82	.959	399,000	111,720
		1969	71	29	.594	1,080,000	766,800
		1970	39	61	.907	1,340,000	522,600
near Brandon	05MH013	1975	38	62	.866	2,140,000	813,200

% Flood Flow

Mean = 48
Range 6 - 71

APPENDIX B

GUIDELINES FOR CANADIAN DRINKING

WATER QUALITY

Table 2
RECOMMENDED LIMITS FOR CHEMICAL SUBSTANCES RELATED TO HEALTH

Substance*	Maximum Acceptable Concentration mg/L	Objective Concentration mg/L
Inorganic		
Antimony	—	≤0.0002
Arsenic	0.05	≤0.005
Barium	1.0	≤0.1
Boron	5.0	≤0.01
Cadmium	0.005	≤0.001
Chromium	0.05	≤0.0002
Cyanide (Free)	0.2	≤0.002
Lead	0.05	≤0.001
Mercury	0.001	≤0.0002
Nitrate (as N)**	10.0	≤0.001
Nitrite (as N)**	1.0	≤0.001
Selenium	0.01	≤0.002
Silver	0.05	≤0.005
Sulphate	500	<150
Uranium	0.02	≤0.001
Organic		
Nitrilotriacetic Acid (NTA)	0.05	≤0.0002
Pesticides (Total)***	0.1	—
Trihalomethanes****	0.35	≤0.0005

* Unless otherwise stated the limits for each substance refer to the sum of all forms present.

** Where both nitrate and nitrite are present, the total nitrate- plus nitrite-nitrogen should not exceed 10 mg/L.

*** For maximum acceptable and objective concentrations of individual pesticides see Table 3.

**** Comprise chloroform, bromodichloromethane, chlorodibromomethane, and bromoform.

(HEALTH AND WELFARE CANADA, 1978)

Table 3
RECOMMENDED LIMITS FOR PESTICIDES

Pesticide*	Maximum Acceptable Concentration mg/L	Objective Concentration mg/L
Aldrin + Dieldrin	0.0007	$\leq 5 \times 10^{-5}$
Carbaryl	0.07	$\leq 5 \times 10^{-3}$
Chlordane (Total Isomers)	0.007	$\leq 5 \times 10^{-4}$
DDT (Total Isomers)	0.03	$\leq 5 \times 10^{-4}$
Diazinon	0.014	$\leq 1 \times 10^{-3}$
Endrin	0.0002	$\leq 5 \times 10^{-5}$
Heptachlor + Heptachlor Epoxide	0.003	$\leq 5 \times 10^{-4}$
Lindane	0.004	$\leq 1 \times 10^{-3}$
Methoxychlor	0.1	$\leq 5 \times 10^{-3}$
Methyl Parathion	0.007	$\leq 1 \times 10^{-3}$
Parathion	0.035	$\leq 1 \times 10^{-3}$
Toxaphene	0.005	$\leq 5 \times 10^{-4}$
2, 4-D	0.1	$\leq 1 \times 10^{-2}$
2, 4, 5-TP	0.01	$\leq 1 \times 10^{-3}$
Total Pesticides**	0.1	—

* The limits on each pesticide refer to the sum of all forms present.

** The "total pesticides" limit applies to water in which more than one of the above pesticides is present, in which case, the sum of their concentrations should not exceed 0.1 mg/L.

Table 4
RECOMMENDED LIMITS FOR SUBSTANCES RELATED TO AESTHETIC AND OTHER CONSIDERATIONS

Contaminant	Maximum Acceptable Concentration mg/L	Objective Concentration mg/L
Chloride	250	<250
Copper	1.0	<1.0
Iron	0.3	<0.05
Manganese	0.05	<0.01
Phenols	0.002	<0.002
Sulphide (as H_2S)	0.05	<0.05
Zinc	5.0	<5.0

APPENDIX C

ADDITIONAL INFORMATION ON AQUIFERS

APPENDIX C - ADDITIONAL INFORMATION ON AQUIFERS

C I - Aquifers adjacent to the Qu'Appelle River at Welby

The area adjacent to the Qu'Appelle River at Welby contains part of the extensive Hatfield Valley Aquifer System, which lies in a large south east trending bedrock valley (figure 4). The major aquifer of the system, the Hatfield Valley Aquifer, is fully or partially hydrologically connected to smaller aquifers (Schriener and Maathuis, 1982).

The Basal Aquifer (hydrologically connected with the Hatfield Valley Aquifer) also lies within the area of interest. It is a heterogenous, anisotropic, blanket aquifer composed of Empress group sand, gravel, and silt, and possibly some glacial stratified deposits.

Within the Basal Aquifer, flow is horizontal and northwards, towards the Hatfield Valley Aquifer. Discharge occurs directly into the Qu'Appelle Valley in the south near Welby, to the southwest at Round Lake, and possibly towards the Assiniboine Valley to the east. Recharge occurs by precipitation.

Under drought conditions water could be derived from the overlying semi-confining layer, which has an estimated 4.8×10^{11} L of water available.

C II - Aquifers adjacent to the Red Deer River near Bindless

Surficial sands and gravels, buried valley deposits, and sandstone and coal lenses in the Upper Cretacous Oldman and Foremost Formations form the major aquifers in the area. The majority of wells produce water from the Oldman Formation, or from the wide, deep bedrock valley which contains the Red Deer River Valley and much of the area to the south of the river (Stevenson and Borneuf, 1975).

Groundwater flow is towards the buried valley and the Red Deer River, and north-eastwards within the buried valley. The main source of recharge is surface infiltration.

Preglacial flood-plain deposits and sand and gravel lenses within or overlying the till deposits have yields ranging from 0.4 to 2 L/sec. Wells in the sand and gravel deposits at the base of the preglacial buried valley have possible yields of 7 to 38 L/sec.

Most wells producing from bedrock aquifers are developed in interbedded sandstone lenses (that can be correlated over large areas) of the Oldman Formation. Yields are estimated at 0.4 to 3.0 L/sec. Where the Oldman has been eroded by the preglacial drainage system, the Foremost Formation subcrops. Estimated yields are 0.7 to 3.0 L/sec.

C III - Aquifers adjacent to the Red Deer River at Drumheller

The significant geologic units of the area are the surficial deposits, the Upper Cretacous Edmonton Formation, and the Upper Cretacous Paskapoo Formation. The Edmonton Formation is the dominant formation of the area, subcropping on the northeast side of the river and under most of the river valley. It consists of sandstone, siltstone, shale, and coal. The Paskapoo Formation, which subcrops on the southwest side of the river, contains sandstone, siltstone, shale, and coal (Borneuf, 1972).

The Paskapoo Formation yields 0.07 to 38 L/sec, depending on the extent and thickness of the sandstone lens. The Edmonton Formation has a more uniform yield distribution, usually between 0.07 to 2.0 L/sec.

Flowing wells, common along the valley, are usually shallow (18-30 m deep) and flow mainly from the Paskapoo Formation. The area adjacent to Drumheller has two flowing wells (one at 0.11 L/sec) and eight flowing springs, flowing at 0.07 to 1.5 L/sec.

C IV - Aquifers adjacent to the North Saskatchewan River at Prince Albert

The wells can be separated into two groups, those less than 30 meters deep, and those 30 to 100 meters deep. The shallow wells are located very close to the North Saskatchewan and Sturgeon Rivers. They tend to have lower conductivity and total alkalinity values than the deeper wells (table 11 and 12). Average conductivity is 450 mm/cm compared to 1845 mm/cm for the deeper wells. Average total alkalinity is 227 mg/L compared to 469 mg/L for the deeper wells. The pumping rates, iron content, and manganese content for both the deep and shallow wells are similar.

TABLE 11

GROUND WATER ADJACENT TO THE NORTH SASKATCHEWAN RIVER AT PRINCE ALBERT - DEEP WELLS

WELL NO.	ACQ. NO.	LOCATION	WELL DEPTH metres	DEPTH TO WATER metres	PUMPING RATE L/sec	CONDUCT micro-mhos/cm	TOTAL ALKAL mg/L	IRON mg/L	MANGANESE mg/L
1	1350	SW 5-12-48-26-W2				728	243		
2	1361	SW -33-49-27-W2	35.48	10.04	0.83	1560	304	2.78	1.00
6	1764	SE -9-48-26-W2	54.86	10.06	0.38	2660	345	4.40	
7	1765	NE 1-30-47-26-W2	57.30	7.50	0.91	1070	307	1.00	
8	1766	SE 5-10-48-26-W2	94.49	7.62	0.76	3240	304	0.80	
9	1767	SE 5-10-48-26-W2	94.49	7.62		3320	313	1.50	
11	1770	16-33-49-26-W2	49.26	24.08	0.19	1470	613	0.10	
12	1771	NW 4-10-50-26-W2	34.63	1.03	0.91	2230	385	4.80	
14	2767	16-33-49-26-W2	49.26	24.08	0.19	1467	628	3.10	0.15
15	2773	NE 1-30-47-26-W2	57.30	7.50	0.91	844	302	8.30	0.60
16	2951	SE 11-3-50-26-W2	48.77	12.80	0.45	2016	337	3.40	0.22
17	3437	NE 1-30-47-26-W2	57.30		0.91	827	325	11.00	0.56
18	3452	SE 3-4-50-26-W2	53.34	4.91	0.83	3000	1580	2.40	0.07
19	3631	16-33-49-26-W2	49.10		0.19	1410	581	5.90	0.12
AVE			56.58	10.66	0.62	1846	469	3.81	0.39
MAX			94.49	24.08	0.91	3320	1580	11.00	1.00
MIN			34.63	1.03	0.19	728	243	0.10	0.07

(Saskatchewan Research Council Water Analysis Reports)

TABLE 12

GROUND WATER ADJACENT TO THE NORTH SASKATCHEWAN RIVER AT PRINCE ALBERT - SHALLOW WELLS

WELL NO	ACQ. NO.	LOCATION	WELL DEPTH metres	DEPTH TO WATER metres	PUMPING RATE L/sec	CONDUCT micro-mho/cm	TOTAL ALKAL mg/L	IRON mg/L	MANGANESE mg/L
3	1468	SE 8-29-49-25-W2	27.84	5.04	17.50	703	369	1.80	
4	1469	SE 8-29-49-25-W2	11.14	5.51	0.23	498	287	3.00	
5	1671	NW15-22-49-26-W2	16.46	9.75	0.91	141	59	7.30	0.19
10	1769	NW15-22-49-26-W2	22.25	12.50	0.76	321	195	5.70	
13	1807	NE 14-3-49-27-W2	17.68	8.84	0.30	400	217	9.00	
20	3642	NE 14-3-49-27-W2	17.68		0.30	532	227	3.10	0.30
21	3818	NE 14-3-49-27-W2	17.68		0.30	552	234	0.48	0.14
AVE			18.68	8.33	2.90	449.57	226.86	4.34	0.21
MAX			27.84	12.50	17.50	703.00	369.00	9.00	0.30
MIN			11.14	5.04	0.23	141.00	59.00	0.48	0.14

(Saskatchewan Research Council Water Analysis Reports)

APPENDIX D

SURFACE WATER QUALITY DATA

ASSINIBOINE RIVER AT BRANDON

SURFACE WATER QUALITY
ASSINIBOINE RIVER AT BRANDON

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
29-Jan-74	21.2	662	228
18-Feb-74	13.7	665	284
15-Mar-74	22.2		279
22-Apr-74	18.9	254	113
06-Aug-74	21.4	613	226
07-Oct-74	17.3	882	290
10-Feb-75	22.4	532	194
28-Apr-75	19.7	361	121
11-Jul-75	24.7	581	219
08-Sep-75	20.2	558	236
03-Feb-76	22.4	969	352
05-Aug-76	22.0	569	218
13-Oct-76	21.5	770	270
09-Feb-77	18.6	712	288
12-May-77	20.3	624	291
18-Aug-77	21.7	578	257
13-Oct-77	22.7	509	257
13-Feb-78	12.9	604	303
AVERAGE	20.2	614.3	245.9
MAXIMUM	24.7	969.0	352.0
MINIMUM	12.9	254.0	113.0

(Environment Canada, 1984b)

SURFACE WATER QUALITY
ASSINIBOINE RIVER AT BRANDON - HIGH FLOW SEASON (APRIL - JULY)

D/M/Y	TEMP C	TDS MG/L	TOTAL ALK MG/L	TURB JTU	IRON extrb MG/L	MANG extrb MG/L	SULPHATE diss MG/L	PHENOLIC MATERIAL MG/L
22-Apr-74	18.9	254	113	98	4.3	0.35	83	0.004
28-Apr-75	19.7	361	121	125	2.9	0.51	139	0.019
11-Jul-75	24.7	581	219	63	1.6	0.36	224	0.027
12-May-77	20.3	624	291	10	0.2	0.16	208	0.001
AVERAGE	20.9	455	186	74	2.3	0.3	164	0.013
MAXIMUM	24.7	624	291	125	4.3	0.5	224	0.027
MINIMUM	18.9	254	113	10	0.2	0.2	83	0.001

(Environment Canada, 1984b)

SURFACE WATER QUALITY
ASSINIBOINE RIVER AT BRANDON - LOW FLOW SEASON (SEPT-FEB)

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
29-Jan-74	21.2	662	228
18-Feb-74	13.7	665	284
07-Oct-74	17.3	882	290
10-Feb-75	22.4	532	194
08-Sep-75	20.2	558	236
03-Feb-76	22.4	969	352
13-Oct-76	21.5	770	270
09-Feb-77	18.6	712	288
13-Oct-77	22.7	509	257
13-Feb-78	12.9	604	303
AVERAGE	19.3	686	270
MAXIMUM	22.7	969	352
MINIMUM	12.9	509	194

(Environment Canada, 1984b)

APPENDIX E

SURFACE WATER QUALITY

QU'APPELLE RIVER NEAR WELBY

SURFACE WATER QUALITY
QU'APPELLE RIVER NEAR WELBY

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
18-Nov-75	15.6	1022	283
18-Dec-75	12.5	1068	295
26-Jan-76	17.8	1113	303
16-Feb-76	18.7	1157	301
17-Mar-76	17.4	1169	316
22-Apr-76	22.1	505	150
18-May-76	20.1	827	226
15-Jun-76	19.1	748	185
20-Jul-76	23.1	932	259
18-Aug-76	20.1	980	268
14-Sep-76	21.7	1008	272
19-Oct-76	18.7	1010	273
23-Nov-76	18.5	1045	289
14-Dec-76	21.2	1030	297
19-Jan-77	17.0	1066	311
20-Feb-77	19.9	1105	312
15-Mar-77	20.1	951	260
21-Apr-77	22.8	884	324
26-May-77	20.3	984	309
22-Jun-77	22.6	1007	303
21-Jul-77	23.6	1466	301
25-Aug-77	21.0	1026	359
22-Sep-77	20.5	916	348
26-Oct-77	18.7	1057	285
24-Nov-77	19.5		336
22-Dec-77	14.9	1027	316
18-Jan-78	16.4	1095	353
22-Feb-78	17.1	1103	397
30-Mar-78	18.7	922	263
18-Apr-78	17.4	788	249
16-May-78	19.5	932	294
19-Jun-78	19.2	1041	259
18-Jul-78	22.8	977	300
23-Aug-78	21.0	857	290
19-Sep-78	19.4	907	324
24-Oct-78	21.0	1088	418
22-Nov-78	21.1	1036	278
06-Dec-78	21.8	1075	305
16-Jan-79	11.6	1093	257
20-Feb-79	22.6	1117	330
12-Mar-79	22.5	1075	275
24-Apr-79	21.7	281	117
12-May-79	9.6	412	128
19-Jun-79	13.0	892	242
23-Jul-79	20.1	686	97
27-Aug-79	22.3	949	257
17-Sep-79	19.5	937	264
15-Oct-79	16.3	975	256
26-Nov-79	17.5	990	258
15-Dec-79	20.6	1017	227

SURFACE WATER QUALITY
QU'APPELLE RIVER NEAR WELBY

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
22-Jan-80	18.0	1078	284
11-Feb-80	22.2	1109	288
25-Mar-80	20.2	833	320
15-Apr-80	22.6	676	220
07-May-80	14.7	976	288
03-Jun-80	19.5	1063	328
22-Jul-80	19.7	852	281
26-Aug-80	22.1	931	305
25-Sep-80	23.1	854	315
24-Oct-80	22.2	998	275
27-Nov-80	21.1	1095	300
08-Dec-80	22.6	874	315
12-Jan-81	19.6	1184	340
23-Feb-81	17.0	637	206
23-Mar-81	21.5	695	263
23-Apr-81	19.1	865	321
25-May-81	18.4	904	357
18-Jun-81	20.8	818	329
27-Jul-81	21.3	887	239
27-Aug-81	19.8	993	287
21-Sep-81	18.8	1034	301
19-Oct-81	23.1	1029	286
23-Nov-81	21.9	1061	231
14-Dec-81	19.8	1174	334
25-Jan-82	19.4	1118	350
22-Feb-82	18.8	1063	340
22-Mar-82	22.2	1034	310
29-Apr-82	21.8	716	200
25-May-82	21.8	941	250
14-Jun-82	20.1	989	265
12-Jul-82	17.8	936	180
09-Aug-82	25.1	932	275
20-Sep-82	21.1	1045	295
25-Oct-82	10.6	1106	275
22-Nov-82	11.8	1121	290
07-Dec-82	19.1	1164	290
AVERAGE	19.5	969	283
MAXIMUM	25.1	1466	418
MINIMUM	9.6	281	97

(Environment Canada, 1984a and 1985a)

SURFACE WATER QUALITY DATA
QU'APPELLE RIVER NEAR WELBY - HIGH FLOW SEASON (APRIL - JULY)

D/M/Y	TEMP	TDS	TOTAL ALKAL	TURB	IRON extrb	IRON diss	MANG extrb	MANG diss	SO4 diss	CADMIUM extrb	CADMIUM tot-rec	PHENOLIC MATERIAL	OIL & GREASE	SURFACT N-ALKYL SULPHNTS
	C	mg/L	mg/L	JTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/ L	mg/L	mg/L
22-Apr-76	22.1	505	150	42	1.31		0.19		10			0.005		0.01
18-May-76	20.1	827	226	12	0.50		0.16		9	0.001		0.005		0.01
15-Jun-76	19.1	748	185	26	0.70		0.23		16			0.007		
20-Jul-76	23.1	932	259	55	0.64		0.43		10					
21-Apr-77	22.8	884	324	17	0.38		0.53		326			0.004		
26-May-77	20.3	984	309	30	0.60		0.43		385			0.004		
22-Jun-77	22.6	1007	303	28	78.00		0.31		400			0.001		
21-Jul-77	23.6	1466	301	40	1.31		0.47		380			0.001		
18-Apr-78	17.4	788	249	48	0.34		1.79		330			0.001		
16-May-78	19.5	932	294	4	1.64		0.36		360			0.002	1.0	
19-Jun-78	19.2	1041	259	124	26.00		0.06		370			0.003		0.01
18-Jul-78	22.8	977	300	27	0.40		0.23		400	0.003		0.001		0.01
24-Apr-79	21.7	281	117	145	4.80		0.71		77					
12-May-79	9.6	412	128	38	0.98		0.16		162			0.006		
19-Jun-79	13.0	892	242	27	1.19		0.26		370			0.002		
23-Jul-79	20.1	686	97	18	0.42		0.36		272			0.004		
15-Apr-80	22.6	676	220	48		0.18		0.05	268			0.002		
07-May-80	14.7	976	288	24				0.03	395		0.001	0.001		
09-Jun-80	19.5	1063	328	26				0.07	440			0.002	4.0	
22-Jul-80	19.7	852	281	14				0.06	325			0.002		0.01
29-Apr-81	19.1	865	321	19				0.17	300			0.002		
25-May-81	18.4	904	357	15				0.60	330		0.003			
18-Jun-81	20.8	818	329	21				0.42	270		0.003	0.001		
27-Jul-81	21.3	887	239	18				0.05	375			0.001		
29-Apr-82	21.8	716	200	68		0.04		0.02				0.001		
25-May-82	21.8	941	250	33				0.02				0.002		
14-Jun-82	20.1	989	265	27				0.03				0.001		
12-Jul-82	17.8	996	180	15				0.06				0.001		
AVERAGE	19.8	872	254	36	7.86	0.11	0.43	0.13	286					
MAXIMUM	23.6	1466	357	145	78.00	0.18	1.79	0.60	440	0.003	0.003	0.007	4.0	0.01
MINIMUM	9.6	281	97	4	0.34	0.04	0.06	0.02	9	0.001	0.001	0.001	1.0	0.01

(Environment Canada, 1984c and 1985a)

SURFACE WATER QUALITY
QU'APPELLE RIVER NEAR WELBY - LOW FLOW SEASON (SEPT-FEB)

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKAL mg/L	IRON extrab mg/L	MERCURY extrab mg/L	MERCURY total mg/L	CADMIUM extrab mg/L
18-Nov-75	15.6	1022	283	0.43	0.14		
18-Dec-75	12.5	1068	295	0.27	0.09		
26-Jan-76	17.8	1113	303	0.31	0.14		
16-Feb-76	18.7	1157	301	0.34	0.10		
14-Sep-76	21.7	1008	272	1.31	0.05		
19-Oct-76	18.7	1010	273	0.53			
23-Nov-76	18.5	1045	289	0.29			
14-Dec-76	21.2	1030	297	0.35			
19-Jan-77	17.0	1066	311	0.36			
20-Feb-77	19.9	1105	312	0.28			
22-Sep-77	20.5	916	348	0.30			
26-Oct-77	18.7	1057	285	0.46			
24-Nov-77	19.5		336	0.25			
22-Dec-77	14.9	1027	316	0.33			
18-Jan-78	16.4	1095	353	0.41			
22-Feb-78	17.1	1103	397	0.29			
19-Sep-78	19.4	907	324	0.41	0.02		
24-Oct-78	21.0	1088	418	1.36			
22-Nov-78	21.1	1096	278	0.40			
06-Dec-78	21.8	1075	305	0.27			
16-Jan-79	11.6	1093	257	0.60			
20-Feb-79	22.6	1117	330	0.68			
17-Sep-79	19.5	937	264	1.20			
15-Oct-79	16.3	975	256				0.006
26-Nov-79	17.5	990	258	0.19			
15-Dec-79	20.6	1017	227	0.11			
22-Jan-80	18.0	1078	284	0.27		0.02	
11-Feb-80	22.2	1109	288	0.20			
25-Sep-80	23.1	854	315				
24-Oct-80	22.2	998	275			0.16	
27-Nov-80	21.1	1095	300			0.02	
08-Dec-80	22.6	874	315			0.05	
12-Jan-81	19.6	1184	340				
23-Feb-81	17.0	637	206				
21-Sep-81	18.8	1034	301			0.02	
19-Oct-81	23.1	1029	286				
23-Nov-81	21.9	1061	291			0.02	
14-Dec-81	19.8	1174	334				
25-Jan-82	19.4	1118	350			0.03	
22-Feb-82	12.8	1063	340				
20-Sep-82	21.1	1045	295			0.02	
25-Oct-82	10.6	1106	275			0.03	
22-Nov-82	11.8	1121	290			0.07	
07-Dec-82	19.1	1164	290			0.02	
AVERAGE	18.7	1043	301				
MAXIMUM	23.1	1184	418	1.36	0.14	0.16	0.006
MINIMUM	10.6	637	206	0.11	0.02	0.02	0.006

(Environment Canada, 1984c and 1985a)

APPENDIX F

SURFACE WATER QUALITY DATA

NORTH SASKATCHEWAN RIVER AT DEER CREEK

SURFACE WATER QUALITY
NORTH SASKATCHEWAN RIVER near DEER CREEK

D/M/Y	TEMP C	TDS mg/l	TOTAL ALKALINITY mg/L
14-Feb-74	20.0	202	128
23-Apr-74	21.9	131	81
21-May-74	22.4	189	127
18-Jun-74	24.6	216	152
23-Jul-74	20.3	196	132
20-Aug-74	20.3	199	138
17-Sep-74	21.2	188	132
22-Oct-74	16.7	188	133
19-Nov-74	22.6	215	148
10-Dec-74	21.7	251	163
23-Jan-75	22.7	219	145
18-Feb-75	22.1	243	148
18-Mar-75	18.2	222	138
20-May-75	23.7	219	136
17-Jun-75	22.5	210	132
14-Jul-75	24.8	199	115
19-Aug-75	21.6	195	122
15-Sep-75	20.4	194	120
21-Oct-75	22.1	208	127
18-Nov-75	15.4	222	141
10-Dec-75	16.7	231	149
21-Jan-76	16.7	222	141
18-Feb-76	19.7	217	132
17-Mar-76	12.1	217	131
22-Apr-76	21.0	176	
19-May-76	21.5	209	113
16-Jun-76	20.7	200	133
28-Jul-76	18.8	181	126
18-Aug-76	21.1	185	112
15-Sep-76	20.5	183	123
20-Oct-76	22.1	181	117
24-Nov-76	14.0	193	129
15-Dec-76	16.8	195	129
19-Jan-77	17.8	210	137
23-Feb-77	19.4	215	132
16-Mar-77	17.4	222	120
14-Apr-77	13.1		103
18-May-77	15.6	200	130
14-Jun-77	21.5	190	130
13-Jul-77	22.1	191	126
17-Aug-77	18.7	181	120
14-Sep-77	19.6	186	127
19-Oct-77	20.5	208	133
16-Nov-77	18.2	220	150
14-Dec-77	13.5	225	144
11-Jan-78	21.4	208	134
15-Feb-78	18.6	194	126
22-Mar-78	12.9	202	124
11-Apr-78	17.5	185	111

SURFACE WATER QUALITY
NORTH SASKATCHEWAN RIVER near DEER CREEK

D/M/Y	TEMP C	TDS mg/l	TOTAL ALKALINITY mg/L
25-May-78	21.4	230	155
15-Jun-78	21.1	175	121
12-Jul-78	22.8	174	121
16-Aug-78	21.1	181	125
13-Sep-78	18.2	206	136
18-Oct-78	20.4	261	218
16-Nov-78	21.7	199	131
13-Dec-78	20.2	201	123
24-Jan-79	21.7	231	150
15-Feb-79	22.5	190	125
11-Apr-79	26.7	215	128
10-May-79	17.6	169	110
13-Jun-79	21.8	193	125
18-Jul-79	17.8	210	132
22-Aug-79	18.8	181	115
12-Sep-79	19.9	181	114
24-Oct-79	21.7	192	122
21-Nov-79	13.0	201	131
05-Dec-79	17.5	216	123
16-Jan-80	11.7	231	138
20-Feb-80	16.8	193	120
19-Mar-80	19.8	170	100
16-Apr-80	24.1	169	100
22-May-80	20.5	177	109
11-Jun-80	20.3	150	104
30-Jul-80	21.5	168	129
13-Aug-80	20.1	192	136
10-Sep-80	20.5	187	130
22-Oct-80	15.5	198	140
19-Nov-80	15.2	229	155
10-Dec-80	18.5	231	160
21-Jan-81	21.9	200	135
18-Feb-81	19.9	232	138
18-Mar-81	18.3	272	155
06-May-81	16.3	215	144
24-Jun-81	21.7	178	130
22-Jul-81	22.5	163	123
19-Aug-81	22.4	180	134
23-Sep-81	20.3	173	125
28-Oct-81	22.2	182	129
18-Nov-81	16.5	181	125
02-Dec-81	23.7	209	143
20-Jan-82	18.2	239	159
16-Feb-82	17.5	213	140
17-Mar-82	20.2	202	130
21-Apr-82	22.8	200	115
12-May-82	21.2	187	120
16-Jun-82	22.9	190	130
14-Jul-82	25.8	148	105
25-Aug-82	23.6	195	140
22-Sep-82	15.8		125
20-Oct-82	14.7	190	135
10-Nov-82	17.4	196	140
15-Dec-82	12.1	216	150
AVERAGE	19.6	200	131
MAXIMUM	26.7	272	218
MINIMUM	11.7	131	81

(Environment Canada, 1984c and 1985a)

SURFACE WATER QUALITY
NORTH SASKATCHEWAN RIVER near DEER CREEK - HIGH FLOW SEASON (APRIL - JULY)

D/M/Y	TEMP	TDS	TOTAL ALK	TURB	IRON extrb	IRON diss	MANG extrb	MANG diss	SO4	CADMIUM	PHENOLOC MATERIAL	NTA	OIL & GREASE	SURFACT N-ALKYL SULPHNTS
	C	mg/L	mg/L	JTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
23-Apr-74	21.9	131	81	310.0	18.00		0.61		26	0.003	0.006			
21-May-74	22.4	189	127	60.0	1.90		0.10		36					
18-Jun-74	24.6	216	152	6.5	0.60		0.04		39	0.002	0.005			
23-Jul-74	20.3	196	132	40.0	0.87		0.05		41		0.002			
20-May-75	23.7	219	136	20.0	0.41		0.05		47		0.007	0.02	1	
17-Jun-75	22.5	210	132	12.0	0.16		0.03		52		0.010			0.02
14-Jul-75	24.8	199	115	10.0	0.19		0.05		54		0.008			0.01
22-Apr-76	21.0	176		26.0	0.92		0.04		32		0.005			
19-May-76	21.5	209	113	15.0	0.38		0.04		52					0.01
16-Jun-76	20.7	200	133	13.0	0.20		0.03		48		0.007			0.01
28-Jul-76	18.8	181	126	13.0	0.24		0.03		47	0.003				
14-Apr-77	13.1		103	28.0	0.89		0.04		37		0.001			0.01
18-May-77	15.6	200	130	43.0	1.50		0.07		41		0.001			0.01
14-Jun-77	21.5	190	130	39.0	1.31				37		0.002			0.01
13-Jul-77	22.1	191	126	122.0	0.22		0.02		42		0.001			
11-Apr-78	17.5	185	120	11.0	0.45		0.02		39		0.004			
25-May-78	21.4	230	155	45.0	1.46		0.10		46					
15-Jun-78	21.1	175	121	118.0	1.44		0.12		33		0.001			0.01
12-Jul-78	22.8	174	121	18.0	0.35		0.03		34		0.001			0.02
11-Apr-79	26.7	215	128	15.0	0.40		0.03		45		0.005			
10-May-79	17.6	169	110	77.0	2.50		0.10		32		0.003			
13-Jun-79	21.8	193	125	21.0	0.42		0.04		36		0.002		1	
18-Jul-79	17.8	210	132	22.0	0.52		0.03		46		0.003			
16-Apr-80	24.1	169	100	40.0		0.09		0.03	37		0.003			
22-May-80	20.5	177	109						44		0.001			0.02
11-Jun-80	20.3	150	104	520.0		0.04			26		0.002			
30-Jul-80	21.5	168	129	13.0					26		0.009			
06-May-81	16.3	215	144	2.4					44		0.002			
24-Jun-81	21.7	178	130	6.2		0.05			32		0.002			
22-Jul-81	22.5	163	123	12.0		0.06		0.02	24					
21-Apr-82	22.8	200	115	9.7					46		0.002			
12-May-82	21.2	187	120	145.0		0.04			42					
16-Jun-82	22.9	190	130	32.0					40		0.001			
14-Jul-82	25.8	148	105	320.0		0.06			26		0.003			
AVERAGE	21.2	188	123	66.2	1.54	0.06	0.08	0.03	39					
MAXIMUM	26.7	230	155	520.0	18.00	0.09	0.61	0.03	54	0.003	0.010	0.02	1	0.02
MINIMUM	13.1	131	81	2.4	0.16	0.04	0.02	0.02	24	0.002	0.001	0.02	1	0.01

(Environment Canada 1984c, and 1985a)

SURFACE WATER QUALITY
NORTH SASKATCHEWAN RIVER near DEER CREEK
LOW FLOW SEASON (SEPT-FEB)

D/M/Y	TEMP C	TDS mg/l	TOTAL ALKALINITY mg/L
14-Feb-74	20.0	202	128
17-Sep-74	21.2	188	132
22-Oct-74	16.7	188	133
19-Nov-74	22.6	215	148
10-Dec-74	21.7	251	163
23-Jan-75	22.7	219	145
18-Feb-75	22.1	243	148
15-Sep-75	20.4	194	120
21-Oct-75	22.1	208	127
18-Nov-75	15.4	222	141
10-Dec-75	16.7	231	149
21-Jan-76	16.7	222	141
18-Feb-76	19.7	217	132
15-Sep-76	20.5	183	123
20-Oct-76	22.1	181	117
24-Nov-76	14.0	193	129
15-Dec-76	16.8	195	129
19-Jan-77	17.8	210	137
23-Feb-77	19.4	215	132
14-Sep-77	19.6	186	127
19-Oct-77	20.5	208	133
16-Nov-77	18.2	220	150
14-Dec-77	13.5	225	144
11-Jan-78	21.4	208	134
15-Feb-78	18.6	194	126
13-Sep-78	18.2	206	136
18-Oct-78	20.4	261	218
16-Nov-78	21.7	199	131
13-Dec-78	20.2	201	123
24-Jan-79	21.7	231	150
15-Feb-79	22.5	190	125
12-Sep-79	19.9	181	114
24-Oct-79	21.7	192	122
21-Nov-79	13.0	201	131
05-Dec-79	17.5	216	123
16-Jan-80	11.7	231	138
20-Feb-80	16.8	193	120
10-Sep-80	20.5	187	130
22-Oct-80	15.5	198	140
19-Nov-80	15.2	229	155
10-Dec-80	18.5	231	160
21-Jan-81	21.9	200	135
18-Feb-81	19.9	232	138
23-Sep-81	20.3	173	125
28-Oct-81	22.2	182	129
18-Nov-81	16.5	181	125
02-Dec-81	23.7	209	143
20-Jan-82	18.2	239	159
16-Feb-82	17.5	213	140
22-Sep-82	15.8		125
20-Oct-82	14.7	190	135
10-Nov-82	17.4	196	140
15-Dec-82	12.1	216	150
AVERAGE	18.8	208	137
MAXIMUM	23.7	261	218
MINIMUM	11.7	173	114

(Environment Canada, 1984c and 1985a)

APPENDIX G

SURFACE WATER QUALITY DATA

NORTH SASKATCHEWAN RIVER AT PRINCE ALBERT

SURFACE WATER QUALITY
NORTH SASKATCHEWAN RIVER AT PRINCE ALBERT

D/M/Y	TEMP . C	TDS mg/L	TOTAL ALKALINITY mg/L
10-Jan-74	14.6	258	164
03-May-74	22.8	213	121
25-Jul-74	23.8	253	151
02-Oct-74	18.8	230	156
28-Jan-75	21.1	257	162
17-Jun-75	20.7	304	170
11-Aug-75	23.2	237	142
30-Jan-76	19.1	263	157
28-Jul-76	24.1	208	116
22-Oct-76	18.9	196	129
11-Jan-77	12.6	231	151
26-Apr-77	22.1	223	127
06-Jul-77	21.4	208	137
23-Aug-77	19.6	207	159
02-Nov-77	21.1	228	155
17-Jan-78	20.1	243	156
AVERAGE	20.3	235	147
MAXIMUM	24.1	304	170
MINIMUM	12.6	196	116

(Environment Canada, 1984c)

SURFACE WATER QUALITY
NORTH SASKATCHEWAN RIVER AT PRINCE ALBERT - HIGH FLOW SEASON (APRIL-JULY)

D/M/Y	TEMP C	TDS mg/L	TOTAL ALK mg/L	TURB JTU	IRON extrb mg/L	MANG extrb mg/L	SO4 diss mg/L	CADMIUM extrb mg/L	PHENOLIC MATERIAL mg/L
03-May-74	22.8	213	121	70	12.50	0.52	55		0.004
25-Jul-74	23.8	253	151	90	3.70	0.15	59		
17-Jun-75	20.7	304	170	9	0.48	0.05	90		0.010
28-Jul-76	24.1	208	116	25	0.45	0.04	59	0.002	0.006
26-Apr-77	22.1	223	127	12	0.26	0.05	56		0.002
06-Jul-77	21.4	208	137	10	0.19	0.03	40		0.007
AVERAGE	22.5	235	137	36	2.93	0.14	60		
MAXIMUM	24.1	304	170	90	12.50	0.52	90	0.002	0.010
MINIMUM	20.7	208	116	9	0.19	0.03	40	0.002	0.002

(Environment Canada, 1984c)

SURFACE WATER QUALITY
NORTH SASKATCHEWAN RIVER AT PRINCE ALBERT - LOW FLOW SEASON (SEPT-FEB)

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
10-Jan-74	14.6	258	164
02-Oct-74	18.8	230	156
28-Jan-75	21.1	257	162
30-Jan-76	19.1	263	157
22-Oct-76	18.9	196	129
11-Jan-77	12.6	231	151
02-Nov-77	21.1	228	155
17-Jan-78	20.1	243	156
AVERAGE	18.3	238	154
MAXIMUM	21.1	263	164
MINIMUM	12.6	196	129

(Environment Canada, 1984c)

APPENDIX H

SURFACE WATER QUALITY DATA

RED DEER RIVER AT BINDLOSS

SURFACE WATER QUALITY
RED DEER RIVER AT BINDLOSS

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
29-Jan-74	21.7	378	282
19-Feb-74	19.3	348	240
20-Mar-74	20.3		239
24-Apr-74	21.4	192	107
22-May-74	22.4	279	174
17-Jun-74	24.4	254	169
22-Jul-74	25.0	201	146
20-Aug-74	20.0	228	143
16-Sep-74	21.5	243	156
21-Oct-74	19.7	263	171
18-Nov-74	20.4	361	227
09-Dec-74	21.8	432	267
20-Jan-75	16.1	445	323
17-Feb-75	22.0	393	283
17-Mar-75	17.6	369	253
22-Apr-75	21.6	247	109
13-May-75	17.2	387	173
16-Jun-75	23.2	287	166
15-Jul-75	25.2	242	151
18-Aug-75	22.3	224	137
16-Sep-75	20.8	238	143
20-Oct-75	20.4	291	168
17-Nov-75	21.2	349	208
09-Dec-75	16.9	507	304
20-Jan-76	23.6	422	283
17-Feb-76	20.1	380	242
18-Mar-76	23.3	423	268
21-Apr-76	21.9	212	127
18-May-76	21.0	292	166
15-Jun-76	20.9	268	145
27-Jul-76	18.1	202	120
17-Aug-76	21.9	194	130
14-Sep-76	20.3	205	135
19-Oct-76	22.3	256	156
23-Nov-76	14.4	378	155
13-Dec-76	17.1	430	305
16-Jan-77	17.4	472	326
12-Feb-77	19.3	319	208
15-Mar-77	21.0	276	157
13-Apr-77	20.9	265	160
17-May-77	14.7	234	145
13-Jun-77	21.3	205	141
12-Jul-77	22.3	204	125
16-Aug-77	18.8	215	156
13-Sep-77	19.5	221	153
18-Oct-77	21.5	262	172
15-Nov-77	18.7	219	40
13-Dec-77	14.0	461	342
10-Jan-78	20.9	388	274
14-Feb-78	18.8	356	249

SURFACE WATER QUALITY
RED DEER RIVER AT BINDLOSS

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
21-Mar-78	13.4	512	324
10-Apr-78	19.8	245	132
24-May-78	21.1	243	166
14-Jun-78	21.3	209	136
11-Jul-78	22.9	203	138
15-Aug-78	21.1	198	132
12-Sep-78	18.1	259	123
17-Oct-78	20.7	310	243
15-Nov-78	22.5	344	225
12-Dec-78	20.3	380	255
23-Jan-79	21.8	432	315
14-Feb-79	22.4	434	320
19-Mar-79	22.3	275	118
10-Apr-79	17.0	239	143
09-May-79	18.3	216	131
12-Jun-79	22.1	230	137
17-Jul-79	18.4	201	122
21-Aug-79	18.9	209	122
11-Sep-79	19.8	201	122
23-Oct-79	22.9	291	153
20-Nov-79	12.9	343	204
04-Dec-79	17.2	445	269
15-Jan-80	11.4	438	320
19-Feb-80	15.8	410	227
18-Mar-80	19.5	378	247
15-Apr-80	22.2	278	190
21-May-80	20.4	279	161
10-Jun-80	21.0	182	127
29-Jul-80	21.6	224	154
12-Aug-80	18.5	250	142
09-Sep-80	21.2	216	150
21-Oct-80	21.3	264	173
18-Nov-80	18.5	330	230
09-Dec-80	21.2	418	288
20-Jan-81	16.3	413	280
17-Feb-81	21.1	392	268
17-Mar-81	19.7	272	164
07-Apr-81	19.9	239	148
05-May-81	16.6	301	197
23-Jun-81	18.6	215	154
21-Jul-81	17.5	200	163
18-Aug-81	25.5	207	158
22-Sep-81	19.3	216	158
27-Oct-81	21.0	271	189
17-Nov-81	23.4	290	205
01-Dec-81	21.8	434	282
19-Jan-82	20.5	589	417
09-Feb-82	18.6	481	380
16-Mar-82	19.4	298	195
20-Apr-82	23.0	227	135
11-May-82	21.0	227	150
15-Jun-82	22.6	233	155
13-Jul-82	27.6	182	135
24-Aug-82	23.8	226	155
21-Sep-82	21.2	238	165
19-Oct-82	12.5	269	185
09-Nov-82	14.6	321	220
14-Dec-82	6.9	465	355
AVERAGE	20.0	301	195
MAXIMUM	27.6	589	417
MINIMUM	6.9	182	40

(Environment Canada, 1984a and 1985a)

SURFACE WATER QUALITY
RED DEER RIVER AT BINDLOSS - HIGH FLOW SEASON (APRIL - JULY)

D/M/Y	TEMP	TDS	TOTAL ALK	TURB	IRON extrb	IRON diss	MANG extrb	IRON diss	SO4 diss	CADMIUM extrb	PHENOLIC MATERIAL	OIL & GREASE	SURFACT N-ALKTL SULPHNTS
	C	mg/L	mg/L	JTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
24-Apr-74	21.4	192	107	320	7.20		0.90		45	0.002	0.005		
22-May-74	22.4	279	174	100	5.10		0.31		65		0.003		
17-Jun-74	24.4	254	169	70	1.20		0.13		56	0.001	0.004	2	
22-Jul-74	25.0	201	146	58	4.80		0.17		36	0.001			
22-Apr-75	21.6	247	109	1054	2.00		0.25		36		0.033		
13-May-75	17.2	387	173	144	3.30		0.30		128	0.001	0.024	2	
16-Jun-75	23.2	287	166	29	0.60		0.06		81		0.008		
15-Jul-75	25.2	242	151	33	0.62		0.07		63		0.009		
21-Apr-76	21.9	212	127	52	1.70		0.09		48		0.006		
18-May-76	21.0	292	166	98	2.10		0.12		83				
15-Jun-76	20.9	268	145	52	0.78		0.08		84		0.007		
27-Jul-76	18.1	202	120	80	1.50		0.13		56	0.002	0.002	1	
13-Apr-77	20.9	265	160	360	5.70		0.48		66		0.001		
17-May-77	14.7	234	145	420	5.80		0.55		55		0.001		
13-Jun-77	21.3	205	141	55	2.00		0.16		40		0.002		
12-Jul-77	22.3	204	125	75	3.40		0.22		53		0.001		
10-Apr-78	19.8	245	132	180	0.36		0.25		62		0.006		0.02
24-May-78	21.1	243	166	98	2.70		0.16		48		0.005		
14-Jun-78	21.3	209	136	464	5.00		0.54		45				0.01
11-Jul-78	22.9	203	138	62	1.16		0.10		43		0.001		0.02
10-Apr-79	17.0	239	143	42	1.74		0.08		58	0.001	0.003		
09-May-79	18.3	216	131	200	3.50		0.17		46		0.002		
12-Jun-79	22.1	230	137	47	1.29		0.08		56		0.008		
17-Jul-79	18.4	201	122	110	3.30		0.19		52				
15-Apr-80	22.2	278	190	800		0.05		0.03	78		0.002		
21-May-80	20.4	279	161	14					76		0.001		
10-Jun-80	21.0	182	127	340					32		0.001		
29-Jul-80	21.6	224	154	94					44		0.001		
07-Apr-81	19.9	239	148	80		0.08			58		0.002		
05-May-81	16.6	301	197	14					42				
23-Jun-81	18.6	215	154	88					68				
21-Jul-81	17.5	200	169	1000		0.06		0.03	70	tot-rec			
20-Apr-82	23.0	227	135	1000		0.10			52	0.002	0.002		
11-May-82	21.0	227	150	44		0.08			44	0.001			
15-Jun-82	22.6	233	155	900					48		0.001		
13-Jul-82	27.6	182	135	400		0.09			24		0.001		
AVERAGE	21.0	237	147	249	2.79		0.23		57				
MAXIMUM	27.6	387	197	1054	7.20	0.10	0.90	0.03	128	0.002	0.033	2	0.02
MINIMUM	14.7	182	107	14	0.36	0.05	0.06	0.03	24	0.000	0.001	1	0.01

(Environment Canada, 1984a and 1985a)

SURFACE WATER QUALITY
RED DEER RIVER AT BINDLOSS - LOW FLOW SEASON (SEPT-FEB)

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
29-Jan-74	21.7	378	282
19-Feb-74	19.3	348	240
16-Sep-74	21.5	243	156
21-Oct-74	19.7	263	171
18-Nov-74	20.4	361	227
09-Dec-74	21.8	432	267
20-Jan-75	16.1	445	323
17-Feb-75	22.0	393	283
16-Sep-75	20.8	238	143
20-Oct-75	20.4	291	168
17-Nov-75	21.2	349	208
09-Dec-75	16.9	507	304
20-Jan-76	23.6	422	283
17-Feb-76	20.1	380	242
14-Sep-76	20.3	205	135
19-Oct-76	22.3	256	156
23-Nov-76	14.4	378	155
13-Dec-76	17.1	430	305
16-Jan-77	17.4	472	326
12-Feb-77	19.3	319	208
13-Sep-77	19.5	221	153
18-Oct-77	21.5	262	172
15-Nov-77	18.7	219	40
13-Dec-77	14.0	461	342
10-Jan-78	20.9	388	274
14-Feb-78	18.8	356	249
12-Sep-78	18.1	259	123
17-Oct-78	20.7	310	243
15-Nov-78	22.5	344	225
12-Dec-78	20.3	380	255
23-Jan-79	21.8	432	315
14-Feb-79	22.4	434	320
11-Sep-79	19.8	201	122
23-Oct-79	22.9	291	153
20-Nov-79	12.9	343	204
04-Dec-79	17.2	445	269
15-Jan-80	11.4	438	320
13-Feb-80	15.8	410	227
09-Sep-80	21.2	216	150
21-Oct-80	21.3	264	173
18-Nov-80	18.5	330	230
09-Dec-80	21.2	418	288
20-Jan-81	16.3	413	280
17-Feb-81	21.1	392	268
22-Sep-81	19.3	216	138
27-Oct-81	21.0	271	189
17-Nov-81	23.4	290	205
01-Dec-81	21.8	434	282
19-Jan-82	20.5	589	417
09-Feb-82	18.6	481	380
21-Sep-82	21.2	238	165
19-Oct-82	12.5	269	185
09-Nov-82	14.6	321	220
14-Dec-82	6.9	465	355
AVERAGE	19.2	350	232
MAXIMUM	23.6	589	417
MINIMUM	6.9	201	40

(Environment Canada, 1984a and 1985a)

APPENDIX I

SURFACE WATER QUALITY DATA

RED DEER RIVER AT DRUMHELLER

SURFACE WATER QUALITY
RED DEER RIVER AT DRUMHELLER, ALBERTA

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
11-Feb-74	16.3	296	220
11-Feb-74	17.2	232	157
13-Mar-74	22.2		224
03-Jun-74	24.1	335	175
09-Aug-74	21.3	227	134
18-Oct-74	18.6	235	180
09-Jan-75	21.7	351	270
20-Jun-75	19.2	228	145
07-Aug-75	22.1	161	114
26-Jan-76	11.5	313	228
03-Aug-76	23.7	171	118
25-Oct-76	19.5	253	175
27-Jan-77	12.2	311	209
02-Jun-77	18.1	174	134
04-Aug-77	20.3	175	117
28-Oct-77	14.1	225	171
21-Nov-77	21.0		
12-Dec-77	21.7		
16-Jan-78	12.5		
13-Mar-78	21.1		
10-Apr-78	12.5	206	134
15-May-78	21.5	213	161
19-Jun-78	19.6	195	151
10-Jul-78	20.7	184	136
22-Aug-78	14.7	198	156
20-Sep-78	17.9	229	178
25-Oct-78	20.5	233	168
08-Nov-78	18.8	254	184
04-Dec-78	21.5	301	230
22-Jan-79	21.7	363	265
20-Feb-79	21.3	228	265
19-Mar-79	18.9		146
01-Apr-79	21.0	255	168
29-May-79	20.7	164	125
11-Jun-79	21.4	163	118
11-Jul-79	22.6	169	106
23-Aug-79	20.3	155	103
26-Sep-79	20.8	187	125
17-Oct-79	13.2	209	143
07-Nov-79	20.4	258	176
06-Dec-79	6.9	323	240
16-Jan-80	21.2	367	274
13-Feb-80	16.9	336	245
12-Mar-80	20.1	324	236
14-Apr-80	20.6	190	120
20-May-80	19.8	193	131
09-Jun-80	22.6	159	118
28-Jul-80	18.9	200	142
29-Aug-80	19.5	183	138

SURFACE WATER QUALITY
RED DEER RIVER AT DRUMHELLER, ALBERTA

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
08-Sep-80	21.2	184	145
20-Oct-80	19.1	225	172
17-Nov-80	18.6	295	226
08-Dec-80	22.1	354	282
19-Jan-81	18.6	306	249
23-Feb-81	20.3	240	137
16-Mar-81	21.8	282	169
06-Apr-81	21.5	204	148
04-May-81	20.2	251	189
24-Jun-81	14.8	191	154
20-Jul-81	16.7	186	144
24-Aug-81	24.1	204	158
21-Sep-81	12.4	195	149
25-Oct-81	18.1	237	184
16-Nov-81	20.4	256	198
10-Dec-81	21.5	338	185
18-Jan-82	19.7	440	345
08-Feb-82	20.5	351	265
15-Mar-82	21.2	304	220
19-Apr-82	22.5	180	120
10-May-82	22.2	222	165
14-Jun-82	18.8	202	155
12-Jul-82	20.4	173	135
23-Aug-82	19.1	200	155
20-Sep-82	14.4	202	155
18-Oct-82	15.8	237	190
08-Nov-82	20.0	274	220
13-Dec-82	8.3	322	260
AVERAGE	19.1	242	177
MAXIMUM	24.1	440	345
MINIMUM	6.9	155	103

(Environment Canada, 1984a and 1985a)

SURFACE WATER QUALITY
RED DEER RIVER AT DRUMHELLER, ALBERTA - HIGH FLOW SEASON (APRIL - JULY)

D/M/Y	TEMP C	TDS mg/L	TOTAL ALK mg/L	TURB JTU	IRON extrb mg/L	IRON diss mg/L	MANG extrb mg/L	MANG diss mg/L	SO4 diss mg/L	CADMIUM extrb mg/L	PHENOLIC MATERIAL mg/L
03-Jun-74	24.1	335	175.0	1.3	0.63		0.03		38	0.003	
20-Jun-75	19.2	228	145.0	225.0	0.40		0.05		53		0.023
02-Jun-77	18.1	174	134.0	88.0	3.20		0.17		22		0.001
10-Apr-78	12.5	206	134.0	92.0					34		0.005
15-May-78	21.5	213	161.0	6.5	0.40		0.03		34		0.002
19-Jun-78	19.6	195	151.0	42.0					28		0.002
10-Jul-78	20.7	184	136.0	5.7					33		
01-Apr-79	21.0	255	168.0	18.0					46		0.003
29-May-79	20.7	164	125.0	59.0	2.50		0.17		28		0.002
11-Jun-79	21.4	163	118.0	4.0					26		0.002
11-Jul-79	22.6	169	160.0	290.0					34		
14-Apr-80	20.6	190	120.0	600.0		0.16		0.07	36		0.002
20-May-80	19.8	193	131.0	1.1					46		0.002
09-Jun-80	22.6	159	118.0	95.0		0.11			23		0.002
28-Jul-80	18.9	200	142.0	230.0					38		0.002
06-Apr-81	21.5	204	148.0	45.0		0.03		0.15	29		0.002
04-May-81	20.2	251	189.0	3.0					40		
24-Jun-81	14.8	191	154.0	10.0					25		
20-Jul-81	16.7	186	144.0	440.0		0.02		0.05	24		0.002
19-Apr-82	22.5	180	120.0	130.0		0.32		0.03	30		0.004
10-May-82	22.2	222	165.0	12.0		0.09			34		
14-Jun-82	18.8	202	155.0	34.0					32		0.001
12-Jul-82	20.4	173	135.0	72.0		0.17			18		0.002
AVERAGE	20.0	202	144.7	108.9	1.43	0.13	0.09	0.08	33		
MAXIMUM	24.1	335	189.0	600.0	3.20	0.32	0.17	0.15	53	0.003	0.023
MINIMUM	12.5	159	118.0	1.1	0.40	0.02	0.03	0.03	18	0.003	0.001

(Environment Canada, 1984a and 1985a)

SURFACE WATER QUALITY
RED DEER RIVER AT DRUMHELLER - LOW FLOW SEASON (SEPT-FEB)

D/M/Y	TEMP C	TDS mg/L	TOTAL ALKALINITY mg/L
11-Feb-74	16.3	296.0	220.0
11-Feb-74	17.2	232.0	157.0
18-Oct-74	18.6	235.0	180.0
09-Jan-75	21.7	351.0	270.0
26-Jan-76	11.5	313.0	228.0
25-Oct-76	19.5	253.0	175.0
27-Jan-77	12.2	311.0	209.0
28-Oct-77	14.1	225.0	171.0
21-Nov-77	21.0		
12-Dec-77	21.7		
16-Jan-78	12.5		
20-Sep-78	17.9	229.0	178.0
25-Oct-78	20.5	233.0	168.0
08-Nov-78	18.8	254.0	184.0
04-Dec-78	21.5	301.0	230.0
22-Jan-79	21.7	363.0	265.0
20-Feb-79	21.3	228.0	265.0
26-Sep-79	20.8	187.0	125.0
17-Oct-79	13.2	209.0	143.0
07-Nov-79	20.4	258.0	176.0
06-Dec-79	6.9	323.0	240.0
16-Jan-80	21.2	367.0	274.0
13-Feb-80	16.9	336.0	245.0
08-Sep-80	21.2	184.0	145.0
20-Oct-80	19.1	225.0	172.0
17-Nov-80	18.6	295.0	226.0
08-Dec-80	22.1	354.0	282.0
19-Jan-81	18.6	306.0	249.0
23-Feb-81	20.3	240.0	137.0
21-Sep-81	12.4	195.0	149.0
25-Oct-81	18.1	237.0	184.0
16-Nov-81	20.4	256.0	198.0
10-Dec-81	21.5	338.0	185.0
18-Jan-82	19.7	440.0	345.0
08-Feb-82	20.5	351.0	265.0
20-Sep-82	14.4	202.0	155.0
18-Oct-82	15.8	237.0	190.0
08-Nov-82	20.0	274.0	220.0
13-Dec-82	8.3	322.0	260.0
AVERAGE	17.9	276.7	207.4
MAXIMUM	22.1	440.0	345.0
MINIMUM	6.9	184.0	125.0

(Environment Canada, 1984a and 1985a)